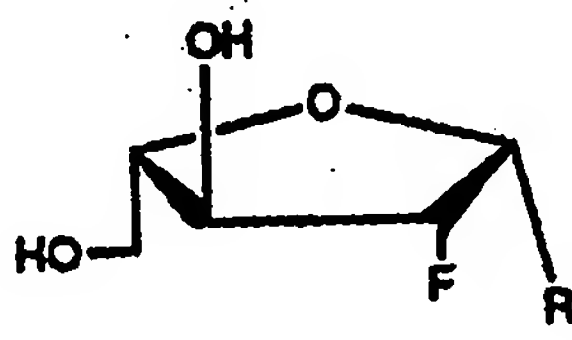


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(54) Title: L-NUCLEOSIDES FOR THE TREATMENT OF HEPATITIS B-VIRUS AND EPSTEIN-BAR VIRUS			
(57) Abstract			
<p>A method for the treatment of a host, and in particular, a human, infected with HBV or EBV is provided that includes administering an HBV- or EBV- treatment amount of an L-nucleoside of formula(I) wherein R is a purine or pyrimidine base. In one preferred embodiment, the active compound is 2'-fluoro-5-methyl-β-L-arabinofuranosyluridine (also referred to as L-FMAU). This compound is a potent antiviral agent against HBV and EBV and exhibits low cytotoxicity. Other specific examples of active compounds include N<sub>1</sub>-(2'-deoxy-2'-fluoro-β-L-arabinofuranosyl)-5-ethyluracil, N<sub>1</sub>-(2'-deoxy-2'-fluoro-β-L-arabinofuranosyl)-5-iodocytosine, and N<sub>1</sub>-(2'-deoxy-2'-fluoro-β-L-arabinofuranosyl)-5-iodouracil.</p>		 <p style="text-align: right;">(I)</p>	

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**L-NUCLEOSIDES FOR THE TREATMENT OF  
HEPATITIS B-VIRUS AND EPSTEIN-BAR VIRUS**

This invention is in the area of methods for the treatment of hepatitis B virus (also referred to as "HBV") and Epstein-Bar Virus (referred to as "EBV") that includes administering an effective amount of one or more of the active compounds disclosed herein, or a pharmaceutically acceptable derivative or prodrug of one of these compounds.

10

**Background of the Invention**

Hepatitis B virus has reached epidemic levels worldwide. After a two to six month incubation period in which the host is unaware of the infection, HBV infection can lead to acute hepatitis and liver damage, that causes abdominal pain, jaundice, and elevated blood levels of certain enzymes. HBV can cause fulminant hepatitis, a rapidly progressive, often fatal form of the disease in which massive sections of the liver are destroyed. Patients typically recover from acute viral hepatitis. In some patients, however, high levels of viral antigen persist in the blood for an extended, or indefinite, period, causing a chronic infection. Chronic infections can lead to chronic persistent hepatitis. Patients infected with chronic persistent HBV are most common in developing countries. By mid-1991, there were approximately 225 million chronic carriers of HBV in Asia alone, and worldwide, almost 300 million carriers. Chronic persistent hepatitis can cause fatigue, cirrhosis of the liver, and hepatocellular carcinoma, a primary liver cancer.

In western industrialized countries, high risk

groups for HBV infection include those in contact with HBV carriers or their blood samples. The epidemiology of HBV is in fact very similar to that of acquired immunodeficiency syndrome, which  
5 accounts for why HBV infection is common among patients with AIDS or HIV-associated infections. However, HBV is more contagious than HIV.

HBV is second only to tobacco as a cause of human cancer. The mechanism by which HBV induces  
10 cancer is unknown, although it is postulated that it may directly trigger tumor development, or indirectly trigger tumor development through chronic inflammation, cirrhosis, and cell regeneration associated with the infection.

15 The Epstein-Barr virus (EBV) is a member of the genus *Lymphocryptovirus*, which belongs to the subfamily *gammaherpesvirinae*. It is notably lymphotropic. EBV has the classic structure of herpesviruses, viz., its double-stranded DNA genome  
20 is contained within an icosapentahedral nucleocapsid, which, in turn, is surrounded by a lipid envelope studded with viral glycoproteins. An amorphous tegument protein occupies the space between the envelope and the nucleocapsid.

25 All human herpesviruses infect and replicate within lymphocytes to some extent, but EBV does so efficiently. Most importantly, the pathogenesis and host responses to infection with EBV are more dependent upon lymphocytic infection than is  
30 evident with the other human herpesviruses.

EBV is now recognized as a cause of B-cell lymphoproliferative diseases, and has been linked to a variety of other severe and chronic illnesses, including a rare progressive mononucleosis-like  
35 syndrome and oral hairy leukoplakia in AIDS patients. The suggestion that EBV is a major cause of chronic fatigue has not withstood scrutiny.

EBV is primarily transmitted through the saliva, although some infections are transmitted by blood transfusion. More than 85% of patients in the acute phases of infectious mononucleosis secrete

5 EBV.

EBV has been associated with cancer. At least two groups of patients are at risk for development of EBV-associated lymphomas: those who have received transplants of kidney, heart, bone marrow, liver, or thymus under the cover of immunosuppressive therapy, and patients with AIDS. EBV-associated cancers include Burkitt's Lymphoma and Nasopharyngeal Carcinoma.

15 In light of the fact that hepatitis B virus and Epstein-Barr virus have severe and often tragic effects on the infected patient, there remains a strong need to provide new effective pharmaceutical agents to treat humans infected with the viruses that have low toxicity to the host.

20 Therefore, it is an object of the present invention to provide a compound, composition, and method for the treatment of hepatitis B virus.

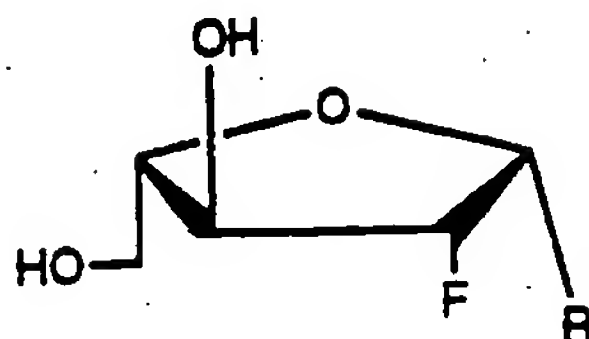
It is another object of the present invention to provide a compound, composition, and method for the treatment of Epstein Barr virus.

25

#### SUMMARY OF THE INVENTION

A method for the treatment of a host, and in particular, a human, infected with HBV or EBV is provided that includes administering an HBV- or

EBV-treatment amount of an L-nucleoside of the formula:



wherein R is a purine or pyrimidine base. In a preferred embodiment, the nucleoside is provided as the indicated enantiomer and substantially in the absence of its corresponding enantiomer (i.e., in enantiomerically enriched, including enantiomerically pure form).

In one preferred embodiment, the active compound is 2'-fluoro-5-methyl- $\beta$ -L-arabinofuranosyluridine (also referred to as L-FMAU). This compound is a potent antiviral agent against HBV and EBV and exhibits low cytotoxicity. Other specific examples of active compounds include  $N_1$ -(2'-deoxy-2'-fluoro- $\beta$ -L-arabinofuranosyl)-5-ethyluracil,  $N_1$ -(2'-deoxy-2'-fluoro- $\beta$ -L-arabinofuranosyl)-5-iodocytosine), and  $N_1$ -(2'-deoxy-2'-fluoro- $\beta$ -L-arabinofuranosyl)-5-iodouracil.

In an alternative embodiment, an L-nucleoside is provided for use in the treatment of HBV or EBV that contains a 2'-arabino-hydroxyl group, for example, L-arathymidine, L-fludarabine, L-ara-guanosine, and L-ara-inosine, as illustrated in Figure 1.

The L-nucleosides disclosed herein and their pharmaceutically acceptable derivatives or pharmaceutically acceptable formulations containing these compounds are useful in the prevention and treatment of HBV infections and other related conditions such as anti-HBV antibody positive and

HBV-positive conditions, chronic liver inflammation caused by HBV, cirrhosis, acute hepatitis, fulminant hepatitis, chronic persistent hepatitis, and fatigue. The compounds can likewise be used in the treatment of EBV-associated disorders. These compounds or formulations can also be used prophylactically to prevent or retard the progression of clinical illness in individuals who are anti-HBV or anti-EBV antibody or HBV- or EBV-antigen positive or who have been exposed to HBV or EBV.

In another embodiment, the active compound or its derivative or salt can be administered in combination or alternation with another anti-HBV agent or anti-EBV agent, including those listed above, or an anti-HIV agent. In general, during alternation therapy, an effective dosage of each agent is administered serially, whereas in combination therapy, an effective dosage of two or more agents are administered together. The dosages will depend on absorption, inactivation, and excretion rates of the drug as well as other factors known to those of skill in the art. It is to be noted that dosage values will also vary with the severity of the condition to be alleviated. It is to be further understood that for any particular subject, specific dosage regimens and schedules should be adjusted over time according to the individual need and the professional judgment of the person administering or supervising the administration of the compositions.

Nonlimiting examples of antiviral agents that can be used in combination with the compounds disclosed herein include the (-)-enantiomer of 2-hydroxymethyl-5-(5-fluorocytosin-1-yl)-1,3-oxathiolane (FTC); the (-)-enantiomer of 2-hydroxymethyl-5-(cytosin-1-yl)-1,3-oxathiolane



(3TC); carbovir, acyclovir, interferon, AZT, DDI (2',3'-dideoxyinosine), DDC (2',3'-dideoxycytidine), L-DDC, L-5-F-DDC and D4T.

#### BRIEF DESCRIPTION OF THE FIGURES

5        Figure 1 is an illustration of selected L-nucleosides that fall within the present invention: L-FMAU (2'-fluoro-5-methyl-β-L-arabinofuranosyluridine), L-FIAU (2'-fluoro-5-iodo-β-L-arabinofuranosyluridine), L-FC (2'-fluoro-β-L-arabinofuranosylcytosine), L-FIAC (2'-fluoro-5-iodo-β-L-arabinofuranosylcytosine), L-2-Cl-2'-F-2'-deoxyadenine, L-FEAU (2'-fluoro-5-ethyl-β-L-arabinofuranosyluridine), L-arathymidine, L-fludarabine, L-araguanosine, and L-ara-inosine.

10       Figure 2 is a graph of the percentage of viable cells versus drug concentration of L-FMAU in H1 cells.

15       Figure 3 is a schematic illustration of the preparation of 1-O-acetyl-2,3,5-tri-O-benzoyl-β-L-ribofuranose (compound 10).

20       Figure 4 is a schematic illustration of an alternative preparation of 1-O-acetyl-2,3,5-tri-O-benzoyl-β-L-ribofuranose (compound 10).

25       Figure 5 is a schematic illustration of a method for the preparation of 1,3,5-tri-O-benzoyl-2-deoxy-2-fluoro-α-L-arabinofuranose (compound 13).

30       Figure 6 is schematic illustration of a method for the preparation of N<sub>9</sub>-[3',5'-di-O-benzoyl-2'-deoxy-2'-fluoro-β-L-arabinofuranosyl]-2,6-di-chloropurine (compound 15) and N<sub>9</sub>-[2'-deoxy-2'-fluoro-β-L-arabinofuranosyl]-2,6-di-chloropurine (compound 16).

35       Figure 7 is an illustration of a method for the preparation of a number of 2'-deoxy-2'-fluoro-β-L-arabinofuranosyl]-pyrimidines (compounds 17-24).



Figure 8 is an illustration of a method for the preparation of N<sub>1</sub>-(2'-deoxy-2'-fluoro-β-L-arabinofuranosyl)-5-iodocytosine (compound 22).

Figure 9 is an illustration of a method for the preparation of 9-β-L-arabinofuranosyladenine.

Figure 10 is an illustration of an alternative route for the preparation of 1-O-acetyl-2,3,5-tri-O-benzoyl-β-L-ribofuranose (compound 10) from 1,2-di-O-isopropylidene-α-L-xylofuranose (compound 3).

Figure 11 is a graph of the plasma concentration of L-(-)-FMAU in mice after oral administration over time (cross, 10 mg/kg administered bid (bi-daily) for 29 days prior to pharmacokinetic study and then study carried out on day thirty on administration of same concentration; dark circle, 50 mg/kg administered bid for 29 days prior to study and then study carried out on day thirty on administration of same concentration; open circle, 50 mg/kg administered for the first time on the first day of the study).

Figure 12 is a graph of the concentration of L-(-)-FMAU in mouse liver after oral administration over time (cross, 10 mg/kg administered bid (bi-daily) for 30 days prior to pharmacokinetic study and then study carried out on day thirty one on administration of same concentration; dark circle, 50 mg/kg administered bid for 30 days prior to study and then study carried out on day thirty one on administration of same concentration; open circle, 50 mg/kg administered for the first time on the first day of the study).

Figure 13a illustrates the change in body weight over thirty days of control BDF1 female mice. Figures 13b and 13c illustrate the change in body weight over thirty days of BDF1 female mice dosed with 10 mg/kg bid (13b) and 50 mg/kg (13c)

L-(-)-FMAU. The body weight presented represents the mean and standard deviation of that of five to seven mice.

5        Figures 14-20 provide the clinical chemistry of mouse plasma after administration of L-(-)-FMAU at 10 mg/kg (three mice) or 50 mg/kg (three mice) bid for thirty days. Figure 14 is a bar chart graph of the concentration of total bilirubin in the mouse plasma in mg/dL. Figure 15 is a bar chart graph of  
10      the concentration of alkaline phosphatase in the mouse plasma in U/L. Figure 16 is a bar chart graph of the concentration of creatinine in the mouse plasma in mg/dL. Figure 17 is a bar chart graph of the concentration of AST (SGOT, serum  
15      glutamic oxalic transaminase) in the mouse plasma in U/L. Figure 18 is a bar chart graph of the concentration of ALT (SGPT, serum glutamic pyruvic transaminase) in the mouse plasma in U/L. Figure  
20      19 is a bar chart graph of the concentration of lactic acid in the mouse plasma in mmol/L. Figure 20 is a bar chart graph of the concentration of lactic dehydrogenase in the mouse plasma in U/L.

#### DETAILED DESCRIPTION OF THE INVENTION

25        As used herein, the term "enantiomerically enriched" refers to a nucleoside composition that includes at least approximately 95%, and preferably approximately 97%, 98%, 99%, or 100% of a single enantiomer of that nucleoside.

30        As used herein, the term alkyl specifically includes but is not limited to C<sub>1</sub> to C<sub>10</sub> alkyl groups, including methyl, ethyl, propyl, butyl, pentyl, hexyl, isopropyl, isobutyl, sec-butyl, t-butyl, isopentyl, amyl, t-pentyl, cyclopentyl, and cyclohexyl.

As used herein, the term acyl specifically includes but is not limited to acetyl, propionyl, butyryl, pentanoyl, 3-methylbutyryl, hydrogen succinate, 3-chlorobenzoate, benzoyl, acetyl,  
5 pivaloyl, mesylate, propionyl, valeryl, caproic, caprylic, capric, lauric, myristic, palmitic, stearic, and oleic.

As used herein, and unless otherwise defined, the term aryl refers to phenyl.

10 The term "protected" as used herein and unless otherwise defined refers to a group that is added to an oxygen or nitrogen atom to prevent its further reaction during the course of derivatization of other moieties in the molecule in  
15 which the oxygen or nitrogen is located. A wide variety of oxygen and nitrogen protecting groups are known to those skilled in the art of organic synthesis.

The term purine or pyrimidine base includes, but  
20 is not limited to, adenine, N<sup>6</sup>-alkylpurines, N<sup>6</sup>-acylpurines (wherein acyl is C(O)(alkyl, aryl, alkaryl, or aralkyl), N<sup>6</sup>-benzylpurine, N<sup>6</sup>-halopurine, N<sup>6</sup>-vinylpurine, N<sup>6</sup>-acetylenic purine, N<sup>6</sup>-acyl purine, N<sup>6</sup>-hydroxyalkyl purine, N<sup>6</sup>-thioalkyl  
25 purine, thymine, cytosine, 6-azapyrimidine, 2-mercaptopyrimidine, uracil, N<sup>5</sup>-alkylpyrimidines, N<sup>5</sup>-benzylpyrimidines, N<sup>5</sup>-halopyrimidines, N<sup>5</sup>-vinylpyrimidine, N<sup>5</sup>-acetylenic pyrimidine, N<sup>5</sup>-acyl pyrimidine, N<sup>5</sup>-hydroxyalkyl purine, N<sup>6</sup>-thioalkyl  
30 purine, 5-azacytidinyl, 5-azauracilyl, triazolopyridinyl, imidazolopyridinyl, pyrrolopyrimidinyl, pyrazolopyrimidinyl.  
Functional oxygen and nitrogen groups on the base can be protected as necessary or desired. Suitable  
35 protecting groups are well known to those skilled in the art, and include trimethylsilyl, dimethylhexylsilyl, t-butyldimethylsilyl, and t-

butyldiphenylsilyl, tritylmethyl, alkyl groups,  
acyl groups such as acetyl, propionyl, butyl,  
methysulfonyl, and p-toluylsulfonyl. It  
specifically includes 5-methyl uracil (thymine), 5-  
5 iodouracil, cytosine, and 5-ethyluracil.

The invention as disclosed herein is a method  
and composition for the treatment of HBV infection,  
EBV infection, and other viruses replicating in a  
like manner, in humans or other host animals such  
10 as HIV, that includes administering an effective  
amount of one or more of the above-identified L-  
nucleosides, or a physiologically acceptable  
derivative, or a physiologically acceptable salt  
thereof, optionally in a pharmaceutically  
15 acceptable carrier. The compounds of this  
invention either possess anti-HBV activity, anti-  
EBV-activity, or are metabolized to a compound or  
compounds that exhibit anti-HBV or anti-EBV  
activity. The compounds disclosed herein can also  
20 be used to treat HBV and EBV associated disorders.

The active compound can be administered as any  
derivative that upon administration to the  
recipient, is capable of providing directly or  
indirectly, the parent compound, or that exhibits  
25 activity itself. Nonlimiting examples are the  
pharmaceutically acceptable salts (alternatively  
referred to as "physiologically acceptable salts"),  
and the 5' and purine or pyrimidine acylated or  
alkylated derivatives of the active compound  
30 (alternatively referred to as "physiologically  
active derivatives"). In one embodiment, the acyl  
group is a carboxylic acid ester (i.e., -C(O)R') in  
which the non-carbonyl moiety (R') of the ester  
group is selected from straight, branched, or  
35 cyclic C<sub>1</sub> to C<sub>10</sub> alkyl, alkoxyalkyl including  
methoxymethyl, aralkyl including benzyl,  
aryloxyalkyl such as phenoxymethyl, aryl including

phenyl optionally substituted with halogen, C<sub>1</sub> to C<sub>4</sub> alkyl or C<sub>1</sub> to C<sub>4</sub> alkoxy, sulfonate esters such as alkyl or aralkyl sulphonyl including methanesulfonyl, the mono, di or triphosphate ester, trityl or monomethoxytrityl, substituted benzyl, trialkylsilyl (e.g. dimethyl-t-butylsilyl) or diphenylmethylsilyl. Aryl groups in the esters optimally comprise a phenyl or benzyl group. The alkyl group can be straight, branched, or cyclic, and is optimally a C<sub>1</sub> to C<sub>10</sub> group.

### I. Synthesis of L-Nucleosides

The L-nucleosides disclosed herein can be prepared as described in detail below, or by other assays known to those skilled in the art.

In the synthetic schemes described below, other standard reagents, including equivalent acids, bases, and solvents can be used in place of those named, as known to those of ordinary skill in the art. A wide range of protecting groups for oxygen or nitrogen can be used, and are disclosed, for example, in Greene, et al., "Protective Groups in Organic Synthesis," John Wiley and Sons, Second Edition, 1991. Suitable oxygen and nitrogen protecting groups, include, for example, a trisubstituted silyl group such as trimethylsilyl, dimethylhexylsilyl, t-butyl dimethylsilyl, t-butyl diphenylsilyl, trityl, alkyl group, acyl groups such as acetyl, propionyl, benzoyl, p-NO<sub>2</sub> benzoyl, benzyl, or toluyl, methylsulfonyl, or p-tolylsulfonyl. Functional oxygen and nitrogen groups on the heterocyclic base should be protected before condensation with the sugar.

Suitable reducing agents include NaBH<sub>4</sub>, diisobutylaluminum hydride (DIBAL-H), lithium borohydride (LiBH<sub>4</sub>), and sodium bis(2-

methoxyethoxy)-aluminum hydride (Red-Al). Suitable oxidizing agents include aqueous acidic chromic acid ( $\text{CrO}_3$ ), sodium dichromate ( $\text{Na}_2\text{CrO}_7$ ), pyridinium chlorochromate (PCC), pyridinium dichromate (PDC),  
5 potassium permanganate ( $\text{KMnO}_4$ ), lead tetraacetate/pyridine, oxygen over a platinum/carbon catalyst,  $\text{RuO}_4$ ,  $\text{RuO}_4/\text{NaIO}_4$ , dimethylsulfoxide/dicyclohexylcarbodiimide (DMSO/DCC) and a proton donor, silver carbonate, triphenylbismuth carbonate, Oppenauer  
10 oxidation (aluminum alkoxides in acetone) and manganese dioxide (for selective oxidation of allylic or benzylic alcohols in the presence of other alcohols).

Friedel-Crafts catalysts (Lewis acids) that can  
15 be used in the condensation reaction include  $\text{SnCl}_4$ ,  $\text{ZnCl}_4$ ,  $\text{TiCl}_4$ ,  $\text{AlCl}_3$ ,  $\text{FeCl}_3$ ,  $\text{BF}_3$ -diethylether, and  $\text{BCl}_3$ . These catalysts require anhydrous conditions because the presence of water reduces their activity. The catalysts are also inactivated in  
20 the presence of organic solvents with active hydrogens, such as alcohols and organic acids. The catalysts are typically used in solvents such as carbon disulfide, methylene chloride, nitromethane, 1,2-dichloroethane, nitrobenzene,  
25 tetrachloroethane, chlorobenzene, benzene, toluene, dimethylformamide, tetrahydrofuran, dioxane, or acetonitrile. Anhydrous aluminum chloride is not soluble in carbon disulfide. Niedballa, et al., J. Org. Chem. 39, 25 (1974). The preferred catalyst  
30 is  $\text{SnCl}_4$ . The preferred solvent is 1,2-dichloroethane. Trimethylsilyl triflate can be used under the same conditions described above for the Friedel-Crafts catalysts. The reaction proceeds at a temperature range of from  $-10^\circ\text{C}$  to  
35  $200^\circ\text{C}$ . Desilylation can be carried out with a variety of reagents, including acetic acid, trifluoroacetic acid, hydrogen fluoride, n-



tetrabutylammonium fluoride, potassium fluoride and pyridinium HCl.

Referring to Figure 3, starting from L-xylose (1a), the key intermediate 1-O-acetyl-2,3,5-tri-O-benzoyl- $\beta$ -L-ribofuranose (10) was synthesized in a total yield of 20% (L. Vargha, *Chem. Ber.*, 1954, 87, 1351; Holy, A., et al., *Synthetic Procedures in Nucleic Acid Chemistry*, V1, 163-67). As shown in Figure 4, compound 10 can also be synthesized from the more expensive starting material L-ribose (Holy, A., et al., *Synthetic Procedures in Nucleic Acid Chemistry*, V1, 163-67). Figure 3 illustrates an alternative synthesis of compound 10 (yield of 53%), which was subsequently fluorinated at C<sub>2</sub> (*J. Org. Chem.*, 1985, 50, 3644-47) to obtain 1,3,5-tri-O-benzoyl-2-deoxy-2-fluoro-L-arabinofuranose (13), which was condensed with different bases through the bromosugar to provide the 2'-deoxy-2'-fluoro-arabinofuranosyl nucleosides in various yields.

**1,2-Di-O-isopropylidene- $\alpha$ -L-xylofuranose (3)**

To 650 ml of anhydrous acetone was added 4 ml of conc. sulfuric acid, 5 g of molecular sieve (4A), 80 g of anhydrous cupric sulfate and 50 g of L-xylose and the mixture was stirred at room temperature for 36 hours. The reaction mixture was filtered and washed thoroughly with acetone, the combined filtrate was neutralized with ammonium hydroxide then evaporated to dryness. Ethyl acetate (200 ml) was added, then filtered and evaporated, yielded an oil which was dissolved in 250 ml of 0.2% HCl solution and stirred at room temperature for 2.5 hours. The pH was adjusted to 8 with sat. NaHCO<sub>3</sub>, then evaporated to dryness, the residue was extracted with ethyl acetate. Removal of the solvent provided a yellow oil of compound 3 (41.7g, 82.3%).



<sup>1</sup>H-NMR(CDCl<sub>3</sub>): δ 5.979 (d, J=3.78Hz, 1H, H-1);  
4.519(d, J=3.6Hz, 1H, H-2); 4.308(bd, 1H, H-3);  
4.080(m, 3H, H-4 and H-5); 1.321(s, 3H, CH<sub>3</sub>); 1.253  
(s, 3H, CH<sub>3</sub>).

5        **1,2-Di-O-isopropylidene-3,5-di-O-o-**  
         **tolylsulfonyl-α-L-xylofuranose (4)**

Compound 3 (40 g, 210 mmol) was stirred in 500  
ml of anhydrous pyridine at 0°C, while TsCl (75 g,  
393 mmol) was dissolved in 100 ml of CHCl<sub>3</sub>, was added  
10 dropwise. After 3 hours, another portion of TsCl  
(50 g, 262 mmol) in 50 ml of CHCl<sub>3</sub>, was added the  
same as above. The mixture was stirred at r.t. for  
24 hrs, then chilled at 0°C, water (10 ml) was  
added, then stirred at r.t. for 30 minutes. The  
15 reaction mixture was poured into 500 ml of ice-  
water, extracted with CHCl<sub>3</sub> (150 ml x 4), washed  
with 1.5M H<sub>2</sub>SO<sub>4</sub> (150 ml x 4), sat.NaHCO<sub>3</sub> (200 ml x  
2), dried (MgSO<sub>4</sub>). Removing solvent gave a brown  
syrup, which upon crystallization from EtOH, gave 4  
20 as a white solid (103.8g, 99%).

<sup>1</sup>H-NMR(CDCl<sub>3</sub>): δ 7.282, 7.836 (m, 8H, OTs); 5.849  
(d, J=3.51Hz, 1H, H-1); 4.661, 4.779 (m, 2H, H-3  
and H-4); 4.193(dd, 1H, H-2); 4.011 (d, 2H, H-5);  
2.448, 2.478 (2s, 6H, -OTs); 1.261, 1.320 (2s, 6H,  
25 CH<sub>3</sub>).

**1,2-Di-O-acetyl-3,5-di-O-p-tolylsulfonyl-α,β-**  
**xylofuranose (5)**

Compound 4 (70 g, 140.5 mmol) was dissolved in  
700 ml of glacial AcOH and 100 ml of Ac<sub>2</sub>O while 50  
30 ml of conc. sulfuric acid was added dropwise at  
0°C. The resulting solution was stirred at r.t  
overnight and then poured into 1L of ice-water,  
extracted with CHCl<sub>3</sub> (200 ml x 4), washed with sat.  
NaHCO<sub>3</sub>, dried (MgSO<sub>4</sub>). After removing solvent in

vacuo, gave 5 as a syrup (84.2 g, crude yield 110%).

**Methyl-3,5-di-O-p-tolylsulfonyl- $\alpha,\beta$ -xylofuranose (6)**

5       The crude 5 (80 g) was stirred in 500 ml of 1% HCl/CH<sub>3</sub>OH at r.t. for 30 hrs. The solvent was removed under reduced pressure, the residue dissolved in 300 ml of CHCl<sub>3</sub>, washed with sat. NaHCO<sub>3</sub>, dried (MgSO<sub>4</sub>). Removal of solvent gave 6 as  
10   a syrup (60 g, 90% from 4).

**Methyl-2-O-benzoyl-3,5-di-O-p-tolylsulfonyl- $\alpha,\beta$ -xylofuranoside (7)**

15       The syrup 6 (60 g, 127 mmol) was dissolved in 200 ml of pyridine and stirred at 0°C, while benzoyl chloride (40 ml, 345 mmol) was added dropwise, the resulting solution was stirred at r.t. for 17 hrs. It was concentrated to about 50 ml, then poured into 300 ml of ice-water, extracted with CHCl<sub>3</sub>, washed with 3N H<sub>2</sub>SO<sub>4</sub> and sat. NaHCO<sub>3</sub>,  
20   dried (MgSO<sub>4</sub>). After evaporation of the solvent, gave 7 as a syrup (71 g, 97%).

**Methyl-2,3,5-tri-O-benzoyl- $\alpha$ - $\beta$ -L-ribofuranoside (9)**

25       The syrup 7 (70 g) and sodium benzoate (100 g, 694 mmol) were suspended in 1200 ml of DMF and mechanically stirred under reflux for 16 hrs. It was cooled to r.t. and then poured into 1L of ice-water, extracted with ether, dried (MgSO<sub>4</sub>). Evaporation of solvent gave a syrup (50 g, 8a and  
30   8b), which was dissolved in 180 ml of pyridine and benzoylated (BzCl, 20 ml, 172 mmol) for 17 hrs at r.t. After work up, gave 9 as a brown syrup (48 g, 83% from 7).

**1-O-acetyl-2,3,5-tri-O-benzoyl- $\beta$ -L-ribofuranose  
(10)**

Compound 9 (26 g, 54.6 mmol) was treated with 275 ml of glacial acetic acid, 55 ml of acetic anhydride and 16 ml of conc. sulfuric acid at 0°C to r.t. for 17 hrs. Then poured into 1L of ice-water, extracted with chloroform (200 ml x 4). The combined extract was washed with sat. NaHCO<sub>3</sub> and dried (MgSO<sub>4</sub>). Removing solvent gave a brown syrup which was treated with ethanol to give 10 as a white solid. (8.8 g, 32%). m.p. 124.7°C, lit. 129-130°C; D form: 130-131°C [ $\alpha$ ]<sub>D</sub> = -45.613 (c 1.0, CHCl<sub>3</sub>), D form: [ $\alpha$ ]<sub>D</sub> = +44.2.

<sup>1</sup>H-NMR(CDCl<sub>3</sub>):  $\delta$  7.317, 8.134 (m, 15H, OBz); 6.437 (s, 1H, H-1); 5.835 (m, 2H, H-2 and H-3); 4.649 (m, 3H, H-4 and H-5); 2.003 (s, 3H, CH<sub>3</sub>COO-).

**1-O-acetyl-2,3,5-tri-O-benzoyl- $\beta$ -L-ribofuranose  
(from L-ribose)**

L-Ribose (5 g, 33.3 mmol) was suspended in 120 ml of 1% HCl/MeOH and stirred at r.t. for 3 hrs, when a clear solution was obtained. The reaction was quenched by adding 30 ml of anhydrous pyridine, then evaporated under reduced pressure. The resulting syrup was coevaporated with pyridine (30 ml x 2), then dissolved in 80 ml of anhydrous pyridine, and stirred at 0°C while benzoyl chloride (20 ml, 172 mmol) was added dropwise. After stirring at r.t. for 17 hrs, the reaction was complete. Water (10 ml) was added and the mixture was stirred at r.t. for 0.5 hr, then concentrated to about 50 ml, poured into 150 ml of ice-water, extracted with chloroform (50 ml x 4), washed successively with 3N H<sub>2</sub>SO<sub>4</sub> (30 ml x 2), sat. NaHCO<sub>3</sub> (30 ml x 3), and dried (MgSO<sub>4</sub>). Removal of the solvent gave 9 as a syrup of 13 g.

The crude 9 was dissolved in 80 ml of HBr/AcOH (45%, w/v) and stirred at r.t. for 1.5 hrs. To this mixture was added glacial acetic acid (50 ml) and the resulting solution stirred at 0°C, while 34  
5 ml of water was added slowly to keep the temperature below 7°C. It was then stirred at r.t. for 1 hr, poured into 200 ml of ice-water, extracted with chloroform (50 ml x 5). The combined extracts were washed with sat. NaHCO<sub>3</sub>,  
10 dried (MgSO<sub>4</sub>). Removal of solvent gave a syrup (13g), which was dissolved in 40 ml of anhydrous pyridine, stirred at 0°C. Acetic anhydride (14 ml, 148.4 mmol) was then added dropwise. After the reaction was completed, it was poured into 150 ml  
15 of ice-water, extracted with chloroform (50 ml x 4), washed successively with 3N H<sub>2</sub>SO<sub>4</sub> (30 ml x 2), sat. NaHCO<sub>3</sub> (50 ml x 2), and dried (MgSO<sub>4</sub>). Removal of solvent and treatment with methanol gave 10 as a white solid (9.2 g, 53.7% from L-ribose).

20 **1,3,5-Tri-O-benzoyl- $\alpha$ -L-ribofuranose (11)**

Compound 10 (9 g, 17.84 mmol) was stirred in 100 ml of CH<sub>2</sub>Cl<sub>2</sub> at 0°C while 70 ml of CH<sub>2</sub>Cl<sub>2</sub> containing HBr (3.2 g, 30.5 mmol) was added in one portion. The mixture was stirred at 0°C for 3.5 hrs, water  
25 (55 ml) was added and the mixture stirred at r.t. for 18 hrs. The organic layer was separated, washed with sat. NaHCO<sub>3</sub>, and dried (MgSO<sub>4</sub>). After evaporation of the solvent, a foam was obtained, which upon recrystallization from CH<sub>2</sub>Cl<sub>2</sub> and n-  
30 hexane, gave 11 as a white solid. (6.2 g, 75.5%). m.p. 137-138°C, lit. 140-141°C,  $[\alpha]_D = -81.960$  (c 0.55, CHCl<sub>3</sub>; D form:  $[\alpha]_D = +83.71$ ).

<sup>1</sup>H-NMR(CDCl<sub>3</sub>):  $\delta$  7.312, 8.187 (m, 15H, OBz); 6.691 (d, J=4.59Hz, H-1); 5.593 (dd, J<sub>4,3</sub>=6.66Hz; J<sub>2,3</sub>=1.8Hz, 1H, H-3); 4.637, 4.796 (m, 4H, H-2, H-4 and  
35 H-5); 2.3 (b, OH).

**1,3,5-Tri-O-benzoyl-2-O-imidazosulfuryl- $\alpha$ -L-ribofuranose (12)**

Compound 11 (5.94 g, 12.84 mmol) was stirred in 50 ml of anhydrous  $\text{CH}_2\text{Cl}_2$  at  $-15^\circ\text{C}$  (dry ice- $\text{CCl}_4$ ).  
5 Anhydrous DMF (15 ml) and sulfuryl chloride (3.2 ml, 3.98 mmol) was added sequentially. The solution was stirred at  $-15^\circ\text{C}$  for 30 minutes and then left at r.t. for 4 hrs. Imidazole (8.7 g, 12.78 mmol) was added in three portions while the  
10 reaction mixture was cooled in an ice bath. It was then stirred at r.t. for 17 hrs. The mixture was poured into 150 ml of ice-water and the water phase extracted with  $\text{CH}_2\text{Cl}_2$  (50 ml x 3). The combined organic layer was washed with water and dried  
15 ( $\text{MgSO}_4$ ). Purification by column (hexane:EtOAc/5:1-1:1) gave 12 as a white solid (3.7g, 49%). m.p.  $124.5\text{--}125.5^\circ\text{C}$ , lit:  $129^\circ\text{C}$ ;  $[\alpha]_D = -68.976$ ; D form:  $+66.154$ .

$^1\text{H-NMR}(\text{CDCl}_3)$ :  $\delta$  6.9, 8.2 (m, 18H, Ar-H); 6.67  
20 (d,  $J=4.4\text{Hz}$ , 1H, H-1); 5.59 (dd, 1H, H-3), 5.21 (dd, 1H, H-2); 4.5, 4.8 (m, 3H, H-4 and H-5).

**1,3,5-Tri-O-benzoyl-2-deoxy-2-fluoro- $\alpha$ -L-arabinofuranose (13).**

A suspension of 12 (3.33 g, 5.62 mmol),  $\text{KHF}_2$   
25 (1.76 g, 22.56 mmol) in 30 ml of 2,3-butanediol was stirred under argon. It was heated to  $150^\circ\text{C}$  while 1 ml of  $\text{HF}/\text{H}_2\text{O}$  (48%, 27.6 mmol) was added and the mixture was stirred at  $160^\circ\text{C}$  for 1.5 hrs. Brine-ice was added to quench the reaction, and then the  
30 solution was extracted with methylene chloride (50 ml x 4). The combined extract was washed with brine, water, sat.  $\text{NaHCO}_3$ , dried over anhydrous magnesium sulfate and activated carbon (Darco-60). It was poured on a silica gel pad (5 cm x 5 cm),  
35 washed with methylene chloride and then EtOAc, to

give a syrup which from 95% EtOH, 13 (1.3 g, 49.8%) was crystallized. m.p. 77-78°C; lit.: 82°C.

<sup>1</sup>H-NMR(CDCl<sub>3</sub>): δ 7.314, 8.146 (m, 15H, OBz); 6.757 (d, J=9.1Hz, 1H, H-1); 5.38 (d, J=48.5Hz, 1H, H-2); 5.630 (dd, J=22.5Hz, 1H, H-3); 4.768 (m, 3H, H-4 and H-5).

**N<sub>9</sub>-[3',5'-Di-O-benzoyl-2'-deoxy-2'-fluoro-β-L-arabinofuranosyl]-2,6-di-chloro-purine (15)**

Compound 13 (464 mg, 1 mmol) was dissolved in 10 ml of methylene chloride while 1.4 ml of HBr/AcOH (45% w/v) was added. The solution was stirred at r.t. for 24 hrs, and then evaporated to dryness. The residue was dissolved in 20 ml of methylene chloride, and washed with water, sat. NaHCO<sub>3</sub>, dried (MgSO<sub>4</sub>). Filtration and evaporation gave the bromosugar 14 (100%, based on TLC).

At the same time, 2,6-di-chloro-purine (378 mg, 2 mmol) was suspended in 15 ml of HMDS and 2 mg of ammonium sulfate, and then refluxed for 2 hrs. The HMDS was evaporated with high vacuum under N<sub>2</sub> to give the white silylated base.

The bromosugar 14 was dissolved in 25 ml of anhydrous 1,2-dichloroethane. The resulting solution was added to the silylated base under N<sub>2</sub>. The mixture was stirred under reflux for 2 days. Chloroform (30 ml) was added, and then washed successively with water (20 ml x 2), sat. NaHCO<sub>3</sub> (20 ml x 2), sat. NaCl solution (20 ml x 2), and dried (MgSO<sub>4</sub>). From CHCl<sub>3</sub>, compound 15 (105 mg, 19.7%) crystallized. m.p. 158°C; D form: 158°C. UV(Methanol): λ<sub>max</sub>: 238.50 nm, 273.0 nm.

<sup>1</sup>H-NMR (300MHz, DMSO-d<sub>6</sub>): δ 8.82 (d, J=1.5Hz, 1H, H-8); 7.49, 8.33 (m, 10H, OBz); 6.767 (dd, J<sub>H-H</sub>=4Hz, K<sub>F-H</sub>=13.8Hz, 1H, H-1'); 5.854 (dq, J=67.4Hz, 1H, H-2'); 5.910 (m, 1H, H-3'); 4.751 (m, 3H, H-4' and H-5').

**N<sub>9</sub>[2'-deoxy-2'-fluoro-β-L-arabinofuranosyl]-2,6-di-chloropurine (16)**

Compound 15 (70 mg, 0.13 mmol) was dissolved in 25 ml of sat. NH<sub>3</sub>/CH<sub>3</sub>OH in a sealed steel bomb and  
5 heated at 90°C for 6 hrs. Removal of solvent under reduced pressure gave a yellow semisolid which was purified by preparative TLC (9:1/CHCl<sub>3</sub>:CH<sub>3</sub>OH). Lyophilization from water and 1,4-dioxane gave a white powder 16 (30 mg, 75%). UV(H<sub>2</sub>O) pH2, λ<sub>max</sub>  
10 212.00 nm, 263.50 nm (ε6711); pH7, λ<sub>max</sub> 213.50nm, 263.00nm (ε7590); pH11, λ<sub>max</sub> 213.5nm, 263.00nm (ε5468).

<sup>1</sup>H-NMR (300MHz, DMSO-d<sub>6</sub>): δ 8.279 (d, J=1.5Hz, 1H, H-8); 7.908 (bs, 2H, NH<sub>2</sub>); 6.321 (dd, J<sub>H-H</sub>=4.4Hz, J<sub>F-H</sub>=13.8Hz, 1H, H-1'); 5.986 (t, 1H, 5'-OH); 5.230  
15 (dt, J<sub>F-H</sub>=52.6Hz, 1H, H-2'); 5.115 (d, 1H, 3'-OH); 4.425 (dq, J<sub>F-H</sub>=19Hz, 1H, H=3'); 3.841 (m, 1H, H-4'); 3.636 (d, 2H, H-5').

**N<sub>1</sub>-(2'-Deoxy-2'-fluoro-3',5'-di-O-benzyl-β-L-arabinofuranosyl)-thymine (17)**

To a solution of 13 (400 mg, 0.86 mmol) in anhydrous CH<sub>2</sub>Cl<sub>2</sub> (10 ml) was added hydrogen bromide in acetic acid (45% w/v, 1.5 ml), and the resulting  
25 solution was stirred at r.t. for 17 hrs. After evaporation of the solvent and coevaporation with toluene, compound 14 was obtained.

At the same time, thymine (215 mg, 1.72 mmol) was refluxed in HMDS (25 ml) under nitrogen for 17 hrs, to get a homogeneous solution. Evaporation of  
30 the solvent gave a silylated thymine.

A solution of 14 in dichloroethane (50 ml) was added to the silylated thymine and the resulting solution was refluxed under nitrogen for 3 days. Water was added and then extracted with CHCl<sub>3</sub>. The  
35 organic layer was washed with water, brine and dried (MgSO<sub>4</sub>). Evaporation of the solvent gave the



crude product, which was purified on preparative TLC using 2% MeOH/CHCl<sub>3</sub> to give 17 (235 mg, 58%). m.p. 99-101°C. UV(Methanol): 230, 264 nm  
[α]<sub>D</sub>=+22.397.

5     <sup>1</sup>H-NMR(CDCl<sub>3</sub>): δ 7.343-8.389 (m, 12H, Ar-H, NH);  
6.34 (dd, J<sub>H-H</sub>=2.97Hz, J<sub>F-H</sub>=28.32Hz, 1H, H-1'); 5.383  
(dd, J<sub>H-H</sub>=2.7Hz, J<sub>F-H</sub>=63.27Hz, 1H, H-2'); 5.565 (dd,  
1H, H-3'); 4.812 (d, 2H, H-5'); 4.466 (m, 1H, H-  
4'); 1.775 (s, 3H, CH<sub>3</sub>). Anal. (C<sub>24</sub>H<sub>21</sub>N<sub>2</sub>O<sub>7</sub>F), C:  
10   61.01; H, 4.57; N: 5.73; F: 3.92.

**N<sub>1</sub>-(2'-Deoxy-2'-fluoro-β-L-arabinofuranosyl)-  
thymine (18)**

Compound 17 (145 mg, 0.309 mmol) was treated with NH<sub>3</sub>/CH<sub>3</sub>OH at r.t. for 18 hrs. After  
15   evaporation of the solvent and purification on preparative TLC (15% MeOH/CHCl<sub>3</sub>, 18 (70 mg, 87.5%) was obtained. m.p. 174-175°C. UV: 264 nm, [α]<sub>D</sub>=-104.36.

H-NMR (DMSO-d<sub>6</sub>): δ 11.401 (s, 1H, NH); 7.575 (s,  
20   1H, H-6); 6.093 (dd, J<sub>H-H</sub>=4.41Hz, J<sub>F-H</sub>=15.6Hz, H-1');  
5.844 (d, 1H, 3'-OH); 5.019 (dt, J<sub>F-H</sub>=53.3Hz, 1H, H-2');  
5.087 (t, 1H, 5'-OH); 4.194 (dq, 1H, H-3');  
3.647 (m, 3H, H-4' and H-5'); 1.781 (s, 3H, CH<sub>3</sub>).  
Anal. (C<sub>10</sub>H<sub>13</sub>N<sub>2</sub>FO<sub>5</sub>), C: 44.80; H: 4.97; N: 10.04; F:  
25   7.03.

**N<sub>1</sub>-(2'-Deoxy-2'-fluoro-3',5'-di-O-benzoyl-β-L-arabinofuranosyl)-5-ethyluracil (19)**

To a solution of 13 in anhydrous dichloromethane (10 ml) was added hydrogen bromide in acetic acid  
30   (45% w/v, 0.97 ml, 5.385 mmol). The solution was stirred at r.t. for 18 hrs, after evaporation of the solvent and coevaporation with toluene, 14 was obtained.

At the same time, 5-ethyluracil (0.75 g, 5.39  
35   mmol) was suspended in HMDS (10 ml) with ammonium

sulfate (5 mg) and refluxed for 5 hrs. under nitrogen to give a homogeneous solution.

The silylated base solution was evaporated to dryness with avoiding the contact of moisture. To  
5 the obtained syrup was added a solution of 14 in anhydrous 1,2-dichloroethane (10 ml). The reaction mixture was stirred at 95°C under nitrogen for 20 hrs, then evaporated under vacuum to dryness to give a yellow solid, which was mixed with 5 ml of  
10 CH<sub>3</sub>OH/CHCl<sub>3</sub> (1:1) and filtered. The filtrate was evaporated to give a residue, which was chromatographed on silica gel column (CH<sub>3</sub>OH/CHCl<sub>3</sub>, 0-1%) to give a white solid 19 (0.557 g, 100%).

<sup>1</sup>H-NMR (DMSO-d<sub>6</sub>): δ 11.55 (s, 1H, NH); 7.51, 8.08  
15 (m, 10H, Ar-H); 7.32 (s, 1H, H-6); 6.29, 6.37 (dd, J<sub>H-H</sub>=3.7Hz, J<sub>F-H</sub>=20Hz, 1H, H-1'); 5.68-5.75 (dd, J<sub>F-H</sub>=20Hz, 1H, H-3'), 5.47-5.65 (dd, J<sub>F-H</sub>=54Hz, 1H, H-2'); 4.62-4.83 (m, 3H, H-4' and H-5'); 2.01, 2.09 (q, 2H, CH<sub>2</sub>-CH<sub>3</sub>); 0.85 (t, 3H, CH<sub>3</sub>).

20 **N<sub>1</sub>-(2'-Deoxy-2'-fluoro-β-L-arabinofuranosyl)-5-ethyluracil (20)**

Compound 19 (500 mg) was dissolved in methanolic ammonia (50 ml) and stirred at r.t. for 44 hrs. The solution was evaporated to dryness to give a  
25 white solid (0.4 g), which was chromatographed on silica gel column. (CH<sub>3</sub>OH/CHCl<sub>3</sub>, 0-5%) to give a white solid 20 (240 mg, 84%). m.p. 158-161°C.

UV(MeOH): λ<sub>max</sub> 260 nm.

<sup>1</sup>H-NMR (DMSO-d<sub>6</sub>): δ 11.42 (s, 1H, NH); 7.57 (s,  
30 1H, H-6'); 6.10, 6.17 (dd, J<sub>H-H</sub>=5.0Hz, J<sub>F-H</sub>=14Hz, 1H, H-1'); 5.88 (bs, 1H, 3'-OH); 5.14, 5.19 (m, 2H, H-2' and 5'-OH); 4.98 (t, 1H, H-3'); 4.22, 4.28 (m, 1H, H-4'); 3.55, 3.78 (m, 2H, H-5') Anal.

(C<sub>11</sub>H<sub>15</sub>N<sub>2</sub>O<sub>5</sub>F): C: 47.93; H: 5.56; N: 10.06; F: 6.68.

**N<sub>1</sub>-(2'-Deoxy-2'-fluoro-3',5'-di-O-benzoyl-β-L-arabinofuranosyl)-N<sup>4</sup>-benzoyl-5-iodocytosine (21)**

To a solution of 13 (150 mg, 0.323 mmol) in anhydrous methylene chloride (5 ml) was added  
5 hydrogen bromide in acetic acid (45% w/v, 0.29 ml, 1.615 mmol). The reaction mixture was stirred at r.t. for 9.5 hrs. After evaporating the solvent and coevaporating with toluene, 15 was obtained as a yellow syrup.

10 At the same time, N<sup>4</sup>-benzoyl-5-iodocytosine (550 mg, 1.615 mmol) was suspended in HMDS (8 ml) with ammonium sulfate (3 mg) and refluxed for 5 hrs. under nitrogen to give a homogeneous solution.

The silylated base solution was evaporated to  
15 dryness with avoiding the contact of moisture. To the obtained syrup was added a solution of 14 in anhydrous 1,2-dichloroethane (10 ml). The reaction mixture was refluxed under nitrogen for 23 hrs, then evaporated to dryness to give a brown syrup,  
20 which was triturated with chloroform (30 ml). The resulting precipitate was filtered off and washed with chloroform. The filtrate and washings were combined and evaporated to give a brown syrup. The product mixture was separated by chromatography on  
25 silica gel column (CH<sub>3</sub>OH/CHCl<sub>3</sub>, 0-1%) to give a white solid 21 (100 mg, 45%).

<sup>1</sup>H-NMR (CDCl<sub>3</sub>): δ 11.40 (bs, 1H, NH); 7.26, 8.20 (m, 17H, Ar-H, H-6 and NH); 6.36, 6.44 (dd, J<sub>HH</sub>=2.8Hz, J<sub>FH</sub>=21Hz, 1H, H-1'); 5.62, 5.68 (dd, 1H,  
30 H-3'); 5.39, 5.56 (dd, 1H, H-2'); 4.58, 4.85 (m, 3H, H-4' and H-5').

**N<sub>1</sub>-(2'-Deoxy-2'-fluoro-β-L-arabinofuranosyl)-5-iodocytosine (22)**

Compound 21 (100 mg, 0.27 mmol) was treated with  
35 sat. NH<sub>3</sub>/MeOH (60 ml) at r.t. for 24 hrs. Silica gel column chromatography (0-10% CH<sub>3</sub>OH/CHCl<sub>3</sub>) gave

compound 22 (35 mg, 71%) as a white solid.  $[\alpha]_D = -65.4$  (c 0.34, CH<sub>3</sub>OH); UV(MeOH):  $\lambda_{max} = 293$  nm.

<sup>1</sup>H-NMR (DMSO-d<sub>6</sub>):  $\delta$  8.04 (s, 1H, H-6); 6.74, 7.94 (s, 1H, NH); 6.01, 6.08 (dd,  $J_{H-H} = 3.9$  Hz,  $J_{F-H} = 16.6$  Hz, 1H, H-1'); 5.85 (d, 1H, 3'-OH); 5.17 (t, 1-H, 5'-OH); 5.08 (t, 1H, H-2'); 4.89 (t, 1H, H-3'); 4.15-4.23 (m, 1H, H-4'); 3.63-3.79 (m, 2H, H-5').

**N<sub>1</sub>-(2'-Deoxy-2'-fluoro-3',5'-di-O-benzoyl- $\beta$ -L-arabinofuranosyl)-5-iodouracil (23)**

10 To a solution of 13 (260 mg, 0.56 mmol) in 10 ml of anhydrous CH<sub>2</sub>Cl<sub>2</sub> was added HBr/AcOH (45%, w/v, 0.5 ml, 2.8 mmol). The reaction mixture was stirred at r.t. for 36 hrs, and then evaporated to dryness. The residue was dissolved in 20 ml of  
15 CH<sub>2</sub>Cl<sub>2</sub>, washed with water (10 ml), sat. NaHCO<sub>3</sub> (10 ml) and dried (MgSO<sub>4</sub>). Filtration and evaporation gave the bromosugar 14 as a syrup.

At the same time, 5-iodouracil (270 mg, 1.12 mmol) was suspended in 10 ml of HMDS and refluxed  
20 for 36 hrs. to give a homogeneous solution. It was evaporated under vacuum to dryness. To this was added a solution of 14 in anhydrous 1,2-dichloroethane, and the resulting solution was refluxed under N<sub>2</sub> for 1.5 days. CHCl<sub>3</sub> (20 ml) was  
25 added, and the solution was washed successively with water (10 ml), brine (10 ml) and sat. NaHCO<sub>3</sub> (10 ml) and then dried (MgSO<sub>4</sub>). Removal of solvent gave a syrup which was crystallized in CH<sub>2</sub>Cl<sub>2</sub> to give 23 as a yellow solid (237 mg, 73%). A part of  
30 this (70 mg) was recrystallized from 2-isopropanol to give a white solid (67 mg). UV(Methanol):  $\lambda_{max}$  230.0 nm, 276.0 nm.

<sup>1</sup>H-NMR (CDCl<sub>3</sub>):  $\delta$  8.4, 7.3 (m, 12H, Ar-H); 6.29 (dd,  $J_{H-H} = 2.43$  Hz,  $J_{F-H} = 21.6$  Hz 1H, H-1'); 5.377 (dd,  $J_{H-H} = 2.8$  Hz,  $J_{F-H} = 61.3$  Hz, 1H, H-2'); 5.55 (dd, 1H, H-3'); 4.865, 4.793 (d, 2H, H-5'); 4.588, 4.502 (m, 1H, H-4').

**N<sub>1</sub>-(2'-deoxy-2'-fluoro-β-L-arabinofuranosyl)-5-iodouracil (24)**

Compound 23 (40 mg, 0.069 mmol) was dissolved in 25 ml of sat. NH<sub>3</sub>/MeOH and stirred at r.t. for 24 hrs, and then evaporated to dryness. The resulting syrup was purified on preparative TLC (5:1/CHCl<sub>3</sub>:MeOH) to give 24 as a solid (19 mg, 74%). UV(MeOH): λ<sub>max</sub> 280.5 nm.

<sup>1</sup>H-NMR (DMSO-d<sub>6</sub>): δ 11.82 (bs, CONH); 8.24 (s, 1H, H-6); 6.082 (dd, J<sub>H-H</sub>=4.45 Hz, J<sub>F-H</sub>=13.7 Hz, 1H, H-1'); 5.947 (d, 1H, 3'-OH); 5.296 (t, 1H, 5'-OH); 5.07 (dt, J<sub>F-H</sub>=53 Hz, 1H, H-2'); 4.24 (bd, J<sub>F-H</sub>=21 Hz, 1H, H-3'); 3.81, 3.55 (m, 3H, H-4', H-5').

**2,3,5-Tri-O-benzyl-L-arabinose**

As illustrated in Figure 9, thirty grams (0.2 mol) of powdered L-arabinose (5) and then 0.4 ml of concentrated sulfuric acid were added to 600 ml (14.8 moles) of anhydrous methanol. The suspension was stirred and heated under gentle reflux to give a clear solution for 2 hrs. The reaction mixture was neutralized with 1.5 g sodium hydrogen carbonate, dried (Na<sub>2</sub>SO<sub>4</sub>), and then evaporated in vacuo to give a heavy syrup 6 which was diluted with 50 ml of freshly purified tetrahydrofuran and reconcentrated (35-40° bath) to remove residual methanol. Freshly purified tetrahydrofuran (400 ml) was added, and the mixture treated with 30 g. of Drierite, 156 g (2.78 mole) of potassium hydroxide, and 200 ml (1.74 mole) of benzyl chloride. The mixture was heated under gentle reflux overnight, cooled, filtered through a thin layer of Celite, and concentrated in vacuo, and then at high vacuo and 100° (bath). The crude, syrupy methyl 2,3,5-tri-O-benzyl-L-arabinoside (7) was dissolved in 400 ml of glacial acetic acid. The hydrolysis mixture is heated at 65-70° for 2

hrs, concentrated in vacuo to one-third its volume,  
and poured into 2.5 L of a mixture of ice water.  
After being seeded (seeded crystals were originally  
obtained by chromatography being eluted with  
5 dichloromethane), the mixture was kept at 5°  
overnight. The aqueous layer was decant from the  
partially crystalline mass, and the latter was  
dissolved in 200 ml of dichloromethane. The  
solution was washed with cold, aqueous sodium  
10 hydrogen carbonate, dried (Na<sub>2</sub>SO<sub>4</sub>), filtered through  
a thin bed of decolorizing carbon, and concentrated  
in vacuo to a thin syrup which was dissolved in 200  
ml of cyclohexane. After being seeded<sup>5</sup>, the  
solution was kept at room temperature for 1 hr. and  
15 at 5° overnight, to give 27.7 g (33.2%) of 2,3,5-  
tri-O-benzyl-L-arabinose (8). m.p. 68-73°C.  
[α]<sub>D</sub><sup>25</sup> = -1.69 [C 2.01, 9:1 (v/v p-dioxane-water)]  
UV(MeOH) λ<sub>max</sub> 220; 300-MHz <sup>1</sup>HNMR(CDCl<sub>3</sub>) δ 3.48-  
3.62(m, 2H, H-5), 3.94-4.18(m, 3H, H-2, 3, 4),  
20 5.33(d, 1H, J=4.07, H-1), 5.29(s, H-1), 7.25-  
7.33(m, 15, H-aromat).

**2,3,5-Tri-O-benzyl-1-O-(p-nitrobenzoyl)-L-  
arabinose (9)**

Compound 8 (Figure 9) (2 g, 4.76 mmole) was  
25 dissolved in 7.5 ml of dichloromethane, and to this  
solution was added a solution of 0.95 g (5.1  
mmoles) of p-nitrobenzoyl chloride in a mixture of  
5 ml dichloromethane and 1.5 ml of pyridine. The  
reaction mixture was kept at room temperature  
30 overnight, and was then washed successively with 1N  
hydrochloric acid (2 X 10 ml), aqueous sodium  
hydrogen carbonate (2 X 10 ml), and water (3 X 30  
ml). Moisture was removed with Na<sub>2</sub>SO<sub>4</sub>, and the  
solution was concentrated in vacuo to give 2.67 g  
35 (98.4%) of a mixture of the anomers of compound 9.  
mp 68-82°C. Further purification by silica gel  
column chromatography (hexanes:acetone, 8:1) raise

the mp to 89-93°C;  $[\alpha]_D^{24}=13.04$  (C6.8, CH<sub>2</sub>Cl<sub>2</sub>),  
UV (MeOH)  $\lambda_{max}$  215.5 and 258.5, 250MHz <sup>1</sup>NMR (CDCl<sub>3</sub>):  
 $\delta$  3.54-3.69 (m, 2H, H-5), 4.06 (m, 1H, H-4'), 4.22  
(m, 1H, H-3'), 4.33 (m, 1H, H-2'), 4.38-4.78 (m,  
5 6H, benzyl CH<sub>2</sub>), 6.50 (d, 1H, J=2.35, H-1), 7.23-  
7.36 (m, 15H, H-aromat of benzyl group), 8.01-8.25  
(m, 4H, H-aromat of nitrobenzoyl group).

10(2,3,5-Tri-O-benzyl- $\beta$ -L-arabinosyl) thymine  
(12)

10 Thymine 0.444 g (3.52 mmole) and ammonium  
sulfate (2 mg) were suspended in  
hexamethyldisilazane 10 ml, which was refluxed  
(140°C) overnight under argon to give a clear  
solution. Excess hexamethyldisilazane was removed  
15 in vacuo while avoiding of contact of moisture to  
give a syrup 11.

Compound 9 (1 g, 1.76 mmole) was added to 17 ml  
of dichloromethane presaturated with anhydrous  
hydrogen chloride at 0°C. After 2 h at 0°C, the  
20 precipitated p-nitrobenzoic acid (0.25 g) was  
removed by filtration, and the filtrate was  
concentrated in vacuo to a thin syrup, and then  
kept at high vacuo pump at room temperature for 2  
hours to give 2,3,5-tri-O-benzyl- $\alpha$ -L-arabinosyl  
25 chloride (10).

Compound 10 thus prepared was dissolved in 15  
ml of anhydrous dichloromethane, and the solution  
was added to a mixture of silylated thymine (11)  
and 3 g of 4A molecular sieve. The reaction  
30 mixture was stirred at room temperature under argon  
for 18h. The reaction mixture was diluted with 50  
ml of dichloromethane, and poured into 2 ml of  
saturated aqueous NaHCO<sub>3</sub> under vigorous stirring.  
White precipitate (tin hydroxide) appeared, which  
35 was filtered out on the bed of celite. The organic  
layer was separated from water and washed with  
water (3 X 30 ml). The aqueous layer was extracted  
with dichloromethane, and the combined



dichloromethane layer was dried over  $\text{Na}_2\text{SO}_4$ , and then evaporated in vacuo to give a syrup which was purified by silica gel column chromatography (chloroform:methanol, 100:1) to give 12 as a syrup  
5 0.68g (73%).  $[\alpha]_D^{25} = -56.71$  (C 0.6,  $\text{CH}_2\text{Cl}_2$ ).  
UV(MeOH)  $\lambda_{\text{max}}$  218 and 265; 300MHz  $^1\text{H}$ NMR( $\text{CDCl}_3$ ):  
 $\delta$  1.67 (d, 3H,  $J=1.11$ ,  $\text{CH}_3$ ), 3.66-3.70 (m, 2H, H-5')  
4.06 (m, 1H, H-4'), 4.13 (t, 1H,  $J=4.7$ , H-3'), 4.24  
(t, 1H,  $J=4.7$ , H-2'), 4.41, 4.54, 4.56 (m, 6H,  
10 benzyl  $\text{CH}_2$ ), 6.28 (d, 1H,  $J=5.24$ , H-1'), 7.15-7.33  
(m, 15H, H-aromat), 7.43 (d, 1H,  $J=1.31$ , H-6).

**1- $\beta$ -L-arabinofuranosylthymine (13)**

Palladium chloride (680 mg, 3.835 mmole) was suspended in 100 ml of methanol, and reduced by  
15 shaking with hydrogen at room temperature. A solution of 450 mg of 12 in 25 ml of methanol was then added to the acidic suspension of palladium black. The reaction mixture was shaken with  
hydrogen at room temperature for 38 hrs. After the  
20 catalyst had been removed, the solution was neutralized with Dowex ( $\text{HCO}_3$ ) to pH 7 and concentrated in vacuo to a white solid which was recrystallized with ethanol to give 13 (105 mg,  
47.7%). m.p. 244-249°C.  $[\alpha]_D^{25} = -91.48$  (0.25,  $\text{H}_2\text{O}$ );  
25 IR(KBr): 1750, 1600 $\text{cm}^{-1}$ (CO); UV(MeOH):  $\lambda_{\text{max}}$  268; 300  
MHz  $^1\text{H}$ NMR( $\text{DMSO}-d_6$ ):  $\delta$ : 1.76 (s, 3H,  $\text{CH}_3$ ), 3.62 (t,  
2H,  $J=4.56$ , H-5') 3.69 (m, 1H, H-4'), 3.90 (t, 1H,  
 $J=3.88$ , H-3'), 3.99 (t, 1H,  $J=4.10$ , H-2'), 5.08 (br  
s, 1H, C'5-OH, exchangeable), 5.42 (d, 1H,  $J=4.24$ ,  
30 C'2-OH or C'3-OH, exchangeable), 5.54 (d, 1H,  
 $J=5.23$ , C'2-OH or C'3-OH, exchangeable), 5.97 (d,  
1H,  $J=4.64$ , H-1'), 7.51 (d, 1H,  $J=0.97$ , H-6), 11.26  
(s, 1H, NH, exchangeable). Anal. Calcd. for  
 $\text{C}_{10}\text{H}_{14}\text{N}_2\text{O}_6$ ; C, 46.51; H, 5.46; N, 10.85; found: C,  
35 46.67; H, 5.63; N, 10.56.

1-(2,3,5-Tri-O-benzyl- $\beta$ -L-arabinosyl)cytosine  
(15)

Cytosine 0.61 g (6 mmole) and ammonium sulfate (2 mg) were suspended in hexamethyldisilazane 15 ml, which was refluxed (140°C) under nitrogen for 2 hours to give a clear solution. The silylated cytosine mixture was evaporated to dryness in vacuo while avoiding of contact with moisture to give a syrup 14.

10 Compound 9 (2.82 g, 5 mmole) was added to 47 ml of dry dichloromethane presaturated with anhydrous hydrogen chloride at 0°C. After 2 hours at 0°C, the precipitated p-nitrobenzoic acid (0.807 g) was removed by filtration, and the filtrate was  
15 concentrated in vacuo to give syrupy 2,3,5-tri-O-benzyl- $\alpha$ -L-arabinosyl chloride (10).

Compound 10 thus prepared was dissolved in 28.5 ml of anhydrous dichloromethane, and the solution was added to a mixture of silylated cytosine (14) and 8.3 g of 4A molecular sieve. The reaction  
20 mixture was stirred at room temperature under nitrogen for 5 days. Then the reaction mixture was then diluted with 50 ml of dichloromethane and 20 ml of water, and poured into 2 ml of saturated  
25 aqueous NaHCO<sub>3</sub> under vigorous stirring. White precipitate (tin hydroxide) appeared, which was filtered out on the bed of celite. The organic layer was separated from water and washed with water (3 X 30 ml). The aqueous layer was extracted  
30 with dichloromethane, and the combined dichloromethane layer was dried over Na<sub>2</sub>SO<sub>4</sub>, and then evaporated in vacuo to give a syrup which was purified by silica gel column chromatography (chloroform: methanol, 96:4) to give 15 as a white  
35 solid which was recrystallized with 2-propanol to give 1.53 g (60%). m.p. 146-148°C,  $[\alpha]_D^{25} = -105.2$  (Cl, CH<sub>2</sub>Cl<sub>2</sub>), UV(MeOH):  $\lambda_{max}$  211.5,  $\lambda_{min}$  272.5, pH1,

pH7;  $\lambda_{\max}$  211.5,  $\lambda_{\min}$  284, pH9. 300MHz  $^1\text{H}$ NMR ( $\text{CDCl}_3$ )  
 $\delta$ : 3.65 (d, 2H,  $J=4.85$ , H-5'), 4.00 (t, 1H,  $J=3.72$ ,  
H-3'), 4.11 (m, 1H, H-4'), 4.28 (m, 1H, H-2'),  
4.38-4.55 (m, 6H, benzyl  $\text{CH}_2$ ), 5.56 (d, 1H,  $J=7.5$ ,  
5 H-5), 6.39 (d, 1H,  $J=4.59$ , H-1'), 7.12-7.31 (m,  
15H, H-aromat), 7.63 (d, 1H,  $J=7.5$ , H-6).

**1- $\beta$ -L-Arabinofuranosylcytosine Hydrochloride  
Salt(16) by Catalytic Hydrogenation of 15**

Palladium chloride (315 mg, 1.78 mmole) was  
10 suspended in 160 ml of methanol, and reduced by  
shaking with hydrogen at room temperature. To the  
acidic suspension of palladium black was then added  
a solution of 300 mg of 15 in 54 ml of methanol.  
The reaction mixture was shaken with hydrogen at  
15 room temperature for 3 hours. After the catalyst  
had been removed, the solution was neutralized with  
Dowex ( $\text{HCO}_3$ ), concentrated in vacuo and then  
purified by preparative TLC ( $\text{MeOH}:\text{CHCl}_3$ , 3:5) to  
give a syrup which was dissolved in 3 ml of  
20 methanol, added 1% HCl solution in MeOH to pH1,  
concentrated to dryness and triturated with  
2-propanol to give 36 mg (22.1%) of 16. m.p. 190-  
194°C,  $[\alpha]_D^{25} = -115.47$  (C 0.07,  $\text{H}_2\text{O}$ ); UV( $\text{H}_2\text{O}$ )  $\lambda_{\max}$  275,  
pH7;  $\lambda_{\max}$  209.5, 273, pH11;  $\lambda_{\max}$  280, pH1; 300 MHz  
25  $^1\text{H}$ NMR ( $\text{DMSO}-d_6$ );  $\delta$  3.61 (d, 2H, H-5'), 3.82 (m, 1H,  
H-4'), 3.93 (m, 1H, H-2' or H-3'), 4.04 (br s, 1H,  
H-2') or H-3'), 5.18 (br s, 1H, C5'-OH,  
exchangeable), 5.61 (br s, 1H, C2'-OH or C3'-OH,  
exchangeable), 5.67 (br s, 1H, C2'-OH or C3'-OH,  
exchangeable), 6.00 (d, 1H,  $J=4.02$ , H-1'), 6.01 (d,  
30 1H,  $J_{5,6}=7.8$ , H-5) 7.92 (d, 1H,  $J_{5,6}=7.8$ , H-6), 8.49  
(br s, 1H, NH, exchangeable), 9.38 (br s, 1H, NH,  
exchangeable).

**1- $\beta$ -L-Arabinofuranosylcytosine Hydrochloride  
Salt (16) by Treatment of Compound 15 with Boron  
Trichloride**

5 ml of 1M boron trichloride in dichloromethane  
5 was cooled at -72°C (dry ice-acetone). A solution  
of 15 (180 mg, 0.351 mmole) in 3 ml of  
dichloromethane was added slowly to the boron  
trichloride solution. After a total reaction time  
of 2.75 hours, the cooling bath was removed and the  
10 solvent and gas were removed in vacuo. The residue  
was dissolved in cold dichloromethane (10 ml) and  
the solution was evaporated to dryness (3 times,  
until a white solid residue was obtained); cold  
saturated sodium hydrogen carbonate solution was  
15 added to adjust the pH to 6-7. The mixture was  
diluted with ethanol, heated to boiling, treated  
with charcoal, and filtered. The filtrate was  
evaporated to dryness to a syrup which was  
dissolved 3 ml of methanol, added 1% HCl solution  
20 in methanol to pH 1, concentrated to dryness and  
trituated with 2-propanol to give 16 (66 mg,  
78.4%).

**9-(2,3,5-Tri-O-benzyl- $\beta$ -L-arabinosyl) adenine  
(18)**

25 Thoroughly dried compound 9 (5 g, 8.8 mmole) was  
added to 82 ml of dichloromethane presaturated with  
anhydrous hydrogen chloride at 0°. After 2 hours  
of reaction at 0°, the precipitated p-nitrobenzoic  
acid (1.53 g) was removed by filtration, and the  
30 filtrate was concentrated in vacuo to a syrup which  
was then kept in full vacuo at room temperature for  
2 hrs. The 2,3,5-tri-O-benzyl- $\alpha$ -L-arabinosyl  
chloride (10) thus prepared was dissolved in 50 ml  
of dichloromethane, and the solution was added to a  
35 mixture of 4.5 g (18.8 mmole) of dried N-  
benzoyladenine<sup>5</sup> (17) and 14.5g of 4A molecular  
sieve. The reaction mixture was stirred at room

temperature for 1 week, filtered through a bed of celite, and concentrated in vacuo to a syrup which was chromatographed on silica gel using hexanes-acetone (3:1,  $R_f=0.22$ ). The product was separated and concentrated in vacuo to a syrup which was dissolved and stirred with methanolic ammonia (20 ml) in a stainless-steel bomb, and heated overnight at 50-55°C. The solution was then concentrated at reduced pressure to give a semisolid which was recrystallized from warm isopropyl alcohol to give 18 2.4g (50.7%). m.p. 128-129°C.  $[\alpha]_D^{27}=-20.04$  (1.04,  $\text{CH}_2\text{Cl}_2$ ); UV( $\text{CH}_2\text{Cl}_2$ ):  $\lambda_{\text{max}}$  213, 258.5; 250MHz  $^1\text{H}$ NMR( $\text{CDCl}_3$ ):  $\delta$  1.95 (br s, 1H, NH, exchangeable), 3.69 (d, 2H,  $J=4.82$ , H-5'), 4.18-4.30 (m, 6H, benzyl  $\text{CH}_2$ ), 4.51-4.64 (m, 3H, H-2',3',4'), 5.73 (br s, 1H, NH, exchangeable), 6.52 (d, 1H,  $J=4.00$ , H-1'), 6.89-6.93, 7.17-7.37 (m, 15H, H-aromat of benzyl group), 8.17 (s, 1H, H-2 or H-8), 8.32 (s, 1H, H-2 or H-8).

20        **9- $\beta$ -L-Arabinofuranosyladenine (19)**

Boron trichloride (5 ml of 1M) in dichloromethane was cooled at -72°C (Dry Ice-acetone). A solution of 18 (150 mg, 0.279 mmole) in 5ml of dichloromethane was added slowly to the boron trichloride solution. After a total reaction time of 3.5 h, the cooling bath was removed, and the solvent and gas were removed in vacuo. The residue was dissolved in cold dichloromethane (10 ml) and the solution was evaporated to dryness (6 times, until a yellow solid residue was obtained). Cold saturated sodium hydrogen carbonate solution was added to adjust the pH 7-8. The mixture was diluted with ethanol, heated to boiling, the suspension filtered through celite, the filtrate was concentrated in vacuo to a syrup which was crystallized with water. 55 mg (74%) of 19 was

obtained. m.p. 256-258°C, UV (H<sub>2</sub>O):  $\lambda_{\max}$  259; 300  
MHz <sup>1</sup>H-NMR(DMSO-d<sub>6</sub>):  $\delta$ : 3.62-3.66 (m, 2H, H-5'),  
3.77 (br s, 1H, H-4'), 4.13 (br s, 2H, H-2', 3'),  
5.12 (t, 1H, J=5.4, C'5-OH, exchangeable), 5.54 (d,  
5 1H, J=3.78, C'2-OH or C'3-OH, exchangeable), 5.63  
(d, 1H, J=4.32, C'2-OH or C'3-OH, exchangeable),  
6.25 (d, 1H, J=4.02, H-1'), 7.25 (br s, 2H, NH<sub>2</sub>,  
exchangeable), 8.13 (s, 1H-H-2 or H-8), 8.18 (s,  
1H, H-2 or H-8).

10 Figure 10 is an illustration of an alternative  
route for the preparation of 1-O-acetyl-2,3,5-tri-  
O-benzoyl- $\beta$ -L-ribofuranose (compound 10) from 1,2-  
di-O-isopropylidene- $\alpha$ -L-xylofuranose (compound 3).  
1,2-Di-O-isopropylidene- $\alpha$ -L-xylofuranose (3)

15 To 650 ml of anhydrous acetone was added 4 ml of  
conc. sulfuric acid, 5 g of molecular sieve (4A),  
80 g of anhydrous cupric sulfate and 40 g of  
L-xylose. The mixture was stirred at r.t. for 36  
hrs. The reaction mixture was then filtered and  
20 washed thoroughly with acetone, the combined  
filtrate was neutralized with ammonium hydroxide  
then evaporated to dryness. Ethyl acetate (200 ml)  
was added, and then filtered and evaporated,  
yielding an oil which was dissolved in 250 ml of  
25 0.2% HCl and solution and stirred at room  
temperature for 2.5 hrs. The pH was adjusted to 8  
with sat. NaHCO<sub>3</sub>, and then evaporated to dryness.  
The residue was extracted with ethyl acetate.  
Removal of the solvent provided a yellow oil of 3  
30 (41.7g, 82.3%). <sup>1</sup>H-NMR(CDCl<sub>3</sub>):  $\delta$  5.979 (d,  
J=3.78Hz, 1H, H-1); 4.519 (d, J=3.6Hz, 1H, H-2);  
4.308 (bd, 1H, H-3); 4.080 (m, 3H, H-4 and H-5);  
1.321 (s, 3H, CH<sub>3</sub>); 1.253 (s, 3H, CH<sub>3</sub>).

**5-O-Benzoyl-1,2-di-O-isopropylidene- $\alpha$ -L-xylofuranose (25)**

Compound 3 (41 g, 215.6 mmol) was stirred in pyridine (150 ml) and  $\text{CH}_2\text{Cl}_2$  (150 ml) at 0 °C. BzCl (27.5 ml, 237 mmol) dissolved in 30 ml of pyridine was added dropwise. After 30 min, water (5 ml) was added and the mixture was evaporated to dryness, dissolved in EtOAc, washed with sat.  $\text{NaHCO}_3$ , and then dried ( $\text{Na}_2\text{SO}_4$ ). Evaporation of solvent gave an orange syrup which was crystallized in  $\text{Et}_2\text{O}$  to give compound 20 (36 g). The mother liquor was evaporated to dryness, and the residue purified by silica gel column chromatography (1%  $\text{CH}_3\text{OH}/\text{CHCl}_3$ ) to give another batch of compound 25 (12 g, total yield 76%). m.p. 82-83°C. lit<sup>1</sup> D form: 83.5-84.5 °C. <sup>1</sup>H-NMR ( $\text{CDCl}_3$ ):  $\delta$  7.43, 8.07 (m, 5H, Ar-H); 5.97 (d, 1H,  $J=3.6\text{Hz}$ , H-1); 4.80 (q, 1H, H-4); 4.60 (d, 1H,  $J=3.6\text{Hz}$ , H-2); 4.40, 4.20 (m, 3H, H-5, H-5', H-3); 3.50 (bs, 1H,  $\text{D}_2\text{O}$  exchange, 3OH); 1.51, 1.32 (2s, 6H, 2 $\text{CH}_3$ ).

**5-O-Benzoyl-1,2-di-O-isopropylidene- $\alpha$ -L-erythro-pentofuranos-3-ulose (26)**

Compound 25 (40 g, 136 mmol) was stirred in 450 ml of  $\text{CH}_2\text{Cl}_2$ . To this was added pyridinium dichromate (PDC, 30.7 g, 81.6 mmol) and  $\text{Ac}_2\text{O}$  (42.3 ml, 448.8 mmol). The mixture was refluxed for 2.5 hrs. The solution was concentrated to 1/5 its original volume, and then ethyl acetate (50 ml) was added, and the solution filtered. The filtrate was poured onto a silica gel pad (10 cm x 5 cm), eluted with EtOAc, the combined eluant was concentrated, and coevaporated with toluene (50 ml x 2). Crystallization from hexane and EtOAc gave 21 as a white solid (38 g, 96%). m.p. 91-93°C,  $[\alpha]_D$ : -132° (c, 1.0,  $\text{CHCl}_3$ ); lit<sup>2</sup> D form: m.p. 93-94.5°C,  $[\alpha]_D$ : +135° (c, 1.0,  $\text{CHCl}_3$ ); IR (KBr): 1773 $\text{cm}^{-1}$  (ArCO), 1730 $\text{cm}^{-1}$  (CO). <sup>1</sup>H-NMR ( $\text{CDCl}_3$ ):  $\delta$  7.97, 7.42 (m, 5H,



Ar-H); 6.14 (d, 1H, J=4.4Hz, H-1); 4.74, 4.68 (m, 2H, H-4, H-2); 4.50 4.44 (m, 2H, H-5, H-5'); 1.52, 1.44 (2s, 6H, 2CH<sub>3</sub>). Anal. Calcd. (C<sub>15</sub>H<sub>16</sub>O<sub>6</sub>): C, 61.64; H, 5.52; Found: C, 61.42; H, 5.53.

5 **5-O-Benzoyl-1,2-di-O-isopropylidene- $\alpha$ -L-erythro-pentofuranos-3-ulose (26)**

Compound 25 (40 g, 136 mmol) was stirred in 450 ml of CH<sub>2</sub>Cl<sub>2</sub>. To this was added pyridinium dichromate (PDC, 30.7 g, 81.6 mmol) and Ac<sub>2</sub>O (42.3 ml, 448.8 mmol). The mixture was refluxed for 2.5 hrs. The solution was concentrated to 1/5 its original volume, and then EtOAc (50 ml) was added. The solution was filtered, the filtrate was poured onto a silica gel pad (10 cm x 5 cm), eluted with EtOAc, the combined eluant was concentrated, and coevaporated with toluene (50 ml x 2).

Crystallization from hexane and EtOAc gave 26 as a white solid (38 g, 96%). m.p 91-93°C, [ $\alpha$ ]<sub>D</sub>: -132° (c, 1.0, CHCl<sub>3</sub>); lit<sup>2</sup> D form: m.p. 93-94.5°C, [ $\alpha$ ]<sub>D</sub>: +135° (c, 1.0, CHCl<sub>3</sub>); IR (KBr): 1773cm<sup>-1</sup> (ArCO), 1730cm<sup>-1</sup> (CO). <sup>1</sup>H-NMR (CDCl<sub>3</sub>):  $\delta$  7.97, 7.42 (m, 5H, Ar-H); 6.14 (d, 1H, J=4.4Hz, H-1); 4.74, 4.68 (m, 2H, H-4, H-2); 4.50 4.44 (m, 2H, H-5, H-5'); 1.52, 1.44 (2s, 6H, 2CH<sub>3</sub>). Anal. Calcd. (C<sub>15</sub>H<sub>16</sub>O<sub>6</sub>): C, 61.64; H, 5.52; Found: C, 61.42; H, 5.53.

25 **1,2-Di-O-isopropylidene- $\alpha$ -L-ribofuranose (27)**

Compound 26 (37 g, 127 mmol) was dissolved in EtOH/H<sub>2</sub>O (400 ml/100 ml) at 0°C, while NaBH<sub>4</sub> (23.3 g, 612 mmol) was added portionwise. The suspension was stirred at r.t. for 4 hrs. It was filtered and the filtrate evaporated to dryness and coevaporated with methanol. After silica gel column chromatography (0-15% CH<sub>3</sub>OH/CH<sub>2</sub>Cl<sub>2</sub>) and crystallization from EtOAc/Hexane, 27 was obtained as white needle (19 g, 79%). m.p. 86-87°C; [ $\alpha$ ]<sub>D</sub>: -31.5° (c, 0.62, CHCl<sub>3</sub>); lit<sup>3</sup>, D form: m.p. 86-87°C, [ $\alpha$ ]<sub>D</sub>: +37° (c, 0.59, CHCl<sub>3</sub>); IR (KBr): 3356 cm<sup>-1</sup>

(OH). <sup>1</sup>H-NMR (CDCl<sub>3</sub>) δ 5.83 (d, 1H, J=3.98Hz, H-1); 4.595 (t, 1H, H-2); 4.055, 3.72 (m, 4H, H-3, H-4, H-5, H-5'); 2.38 (d, 1H, D<sub>2</sub>O exchange, 3-OH); 1.83 (t, 1H, D<sub>2</sub>O exchange, 5-OH); 1.58, 1.38 (2s, 6H, 2CH<sub>3</sub>). Anal. Calcd. (C<sub>8</sub>H<sub>14</sub>O<sub>5</sub>): C, 50.50; H, 7.42; Found: C, 50.62; H, 7.46.

**3,5-Di-O-Benzoyl-1,2-di-O-Isopropylidene-α-L-ribofuranose (28)**

Compound 27 (19 g, 100 mmol) was stirred in 300 ml of pyridine at 0°C, while BzCl (40 ml, 348 mmol) was added dropwise and then stirred at 4.t. for 3 hrs. The solvent was evaporated to dryness. The residue was extracted with EtOAc, washed with sat. NaHCO<sub>3</sub>, dried (Na<sub>2</sub>SO<sub>4</sub>), evaporation of solvent and crystallization in either gave 23 as a white solid of 39g (98%) m.p. 83-85°C. <sup>1</sup>H-NMR (CDCl<sub>3</sub>): δ 8.07, 7.36 (m, 10H, Ar-H); 5.94 (d, 1H, J=3.6Hz, H-1); 5.05, 5.00 (m, 1H, H-2); 4.73, 4.63 (m, 3H, H-4, H-5, H-5'); 1.58, 1.35 (2s, 6H, 2CH<sub>3</sub>). Anal. Calcd. (C<sub>22</sub>H<sub>22</sub>O<sub>7</sub>): C, 66.50; H, 5.64; Found: C, 66.32; H, 5.57.

**1-O-Acetyl-2,3,5-tri-O-benzoyl-β-L-ribofuranose (31)**

Compound 28 (38 g, 95 mmol) was stirred in 300 ml of 1% HCl/CH<sub>3</sub>OH at r.t. for 30 hrs. Pyridine (20 ml) was added and then the solution was evaporated to dryness. The residue was coevaporated with pyridine (30 ml x 2), and then dissolved in 100 ml of anhydrous pyridine at 0°C while BzCl (17 ml, 146 mmol) was added dropwise, then stirred at r.t. for 3 hrs. The solvent was evaporated, and the residue was dissolved in EtOAc, washed with 0.5 N HCl and then sat. NaHCO<sub>3</sub>, and then dried (Na<sub>2</sub>SO<sub>4</sub>).

Evaporation of solvent gave crude 30 as a syrup.

The crude 30 was stirred in glacial acetic acid (400 ml), and then Ac<sub>2</sub>O (100 ml) at 0°C while conc. H<sub>2</sub>SO<sub>4</sub> (10 ml) was added dropwise. This solution was

stirred at r.t. overnight. The mixture was poured into ice-water, extracted with  $\text{CHCl}_3$ , neutralized with sat.  $\text{NaHCO}_3$ , and then dried ( $\text{Na}_2\text{SO}_4$ ). After evaporation of solvent, a light yellow syrup was obtained, which was crystallized in methanol to give 31 as a white solid of 23.89 g (49.6%, from 28-31). m.p. 124.7 °C,  $[\alpha]_D = 45.613$  (c 1.0,  $\text{CHCl}_3$ ); lit<sup>4</sup>, m.p.: 129-130 °C,  $[\alpha]_D = -43.6$  (c 1.0,  $\text{CHCl}_3$ ). <sup>1</sup>H-NMR( $\text{CDCl}_3$ ):  $\delta$  7.317, 8.134 (m, 15H, OBz); 6.437 (s, 1H, H-1); 5.835 (m, 2H, H-2 and H-3); 4.649 (m, 3H, H-4 and H-5); 2.003 (s, 3H,  $\text{CH}_3\text{COO}^-$ )

## II. Biological Activity

The compounds disclosed herein can be evaluated for activity against HBV and EBV as disclosed in detail below, or by other methods known to those skilled in the art.

### Example 1 Biological Activity Against HBV

Human hepatoma cells with HBV (2.2.15 cells) were used in the assay. These cells were grown to confluence in minimal essential medium with 10% fetal bovine serum. The media was changed at 3-day intervals. At confluence the treatment with the drugs was initiated and then continued for three days. Another addition of the same concentration of the drug was given at this point after removal of the media from the cultures and cultures maintained for an additional period of 3 days. The medium after the 6-day treatment was harvested and the viral particles precipitated by the polyethylene glycol method. The particles were subsequently digested and then processed for Southern analysis. The blots were hybridized to an HBV-specific probe and viral DNA amounts assessed in comparison to DNA levels from cultures not

treated with the drugs. The genomic DNA was digested with Hind III and subjected to Southern analysis. Levels of the episomal DNA were determined in relation to the integrated HBV DNA.

- 5 The drug concentrations that cause 50% inhibition of the DNA ( $ID_{50}$ ) as compared to the controls were calculated. The results are summarized in Table I.

Table 1

Inhibition of HBV by L-Nucleosides

Compound	Anti-HBV Activity ID <sub>50</sub> (μM)	MT2 CD <sub>50</sub> (μM)	CEM CD <sub>50</sub>	CD <sub>50</sub> (μM) (H1 cells)
L-FMAU	0.1	100	>100	1000
D-FMAU	2.0	8-9	10	50
D-FEAU	5.0	100	90	2000
L-FEAU	>5.0	100	>100	900

5

10

**Example 2 Biological Activity Against EBV**

H1 cells were maintained in long phase growth for two days prior to the initiation of treatment. The cells were centrifuged at 600 g for 10 min. at room temperature to separate them from the medium containing pre-existing virus particles. The H1 cells were seeded in 24 well plates at a density of  $1 \times 10^5$  cells per well in 2 ml of fresh medium with or without drug and incubated at 37°C for 5 days. The medium containing virion was saved and used for evaluating the inhibitory effect of drugs on virus production and infectivity by use of a bioassay. The virion were pelleted from the cell free medium by centrifugation at 45,000 rpm for 90 min. in a SW-50 Ti rotor (Beckman). The virion were resuspended in 1 ml growth medium and then used to infect  $1 \times 10^6$  Raji cells for 48 hours. Since the level of EBV DP activity in Raji cells post superinfection is proportional to the number of virions added, the EBV specific DP activity induced was able to be measured. The inhibitory drug effect was calculated by comparing the EBV DP activity to multiple dilution controls. No inhibition of mitochondrial DNA content in H1 cells was observed when the cells were treated by 1 mM L-FMAU for 6 days.

Slot Blot Assay - The amount of mitochondrial DNA was measured by the slot blot method (2).  $2 \times 10^5$  of the treated and non-treated H1 cells were lysed in 200  $\mu$ l of 10 mM of Tris.HCl (pH 7.5) solution by the freeze/thaw method. The cell lysate was treated with 10  $\mu$ g/ml of RNase A at 37°C for 30 min, and then proteinase K (100  $\mu$ g/ml) at 55°C for 2 hours. Equal amounts of 20 X SSC buffer was added to each cell lysate. After boiling for 10 min, the samples were spotted onto nylon membranes (Hybond-N, Amersham Corp.). A

radiolabelled human mitochondrial DNA fragment was used as a probe for DNA hybridization. The same membranes were reprobed with human Alu DNA after removing the mitochondrial DNA probe. The amount  
5 of mitochondrial DNA in the treated and non-treated H1 cells was quantified by densitometer (LKB Ultrosan XL).

The results are provided in Table 2.



Table 2

	Drugs	CD <sub>50</sub> (μM)	ID <sub>90</sub> (μM)	Therapeutic Index (CD <sub>50</sub> /ID <sub>90</sub> )
5	PFA	1200 ± 100	75 ± 5	16
	DHPG	75 ± 6	5 ± 1	15
	ACV	1000 ± 75	50 ± 8	20
	PCV	500 ± 55	20 ± 2	25
	L-FMAU	1000 ± 80	5 ± 0.8	200
10	D-FMAU	50 ± 10	0.1 ± 0.02	50
	L-FEAU	900 ± 70	60 ± 11	15
	D-FEAU	2000 ± 80	1 ± 0.05	2000
	L-FIAC	400 ± 35	< 10	> 40
	D-FIAC	125 ± 15	5 ± 0.5	25
15	L-FIAU	240 ± 20	20 ± 4	12
	D-FIAU	20 ± 4	0.5 ± 0.05	40

Inhibitory effect of compounds on EBV: The CD<sub>50</sub> was performed by exposing H1 cells to different concentrations of the compounds in normal growth medium at 37°C for 72 hours; the cells were then counted and compared with controls. H1 cells were treated for 5 days and the ID<sub>90</sub> was determined by bioassay.

### Example 3 Clearance of L-(-)-FMAU from Plasma and Liver

The clearance of L-(-)-FMAU from the plasma and liver of mice after oral administration was evaluated. Mice were injected with L-(-)-FMAU which was tritium labeled (radiospecificity of 9.3  $\mu\text{mol}/\mu\text{Ci}$ ).

Figure 11 is a graph of the plasma concentration of L-(-)-FMAU in mice after oral administration over time, and Figure 12 is a graph of the concentration of L-(-)-FMAU in mouse liver after oral administration over time (cross, 10 mg/kg administered bid (bi-daily) for 30 days prior to pharmacokinetic study and then study carried out on day thirty one on administration of same concentration; dark circle, 50 mg/kg administered bid for 30 days prior to study and then study carried out on day thirty one on administration of same concentration; open circle, 50 mg/kg administered for the first time on the first day of the study).

At the times indicated (see Figures 10 and 11) the mice were bled from their retro-orbital sinus using heparinized capillaries. The plasma was extracted with trichloroacetic acid and neutralized with freon/trioctylamine. Supernatants were directly counted and the concentration calculated.

As indicated in Figures 10 and 11, the peak concentration of L-(-)-FMAU in the plasma and liver occurred at approximately one hour. The compound was substantially cleared from both plasma and liver after four hours.

#### Example 4 Toxicity of L-(-)-FMAU in BDF1 Female Mice

35      Figure 13a illustrates the change in body weight  
over thirty days of control BDF1 female mice.

Figures 13b and 13c illustrate the change in body weight over thirty days of BDF1 female mice dosed with 10 mg/kg (13b) and 50 mg/kg (13c) bid of L-(-)-FMAU. The body weight presented represents the mean and standard deviation of that of five to seven mice. As indicated in Figures 13b and 13c, L-(-)-FMAU did not appear to significantly affect the weight of the mice over thirty days, indicating that the compound was well tolerated.

10    **Example 5      Clinical Chemistry of Mouse Plasma  
                         after L-(-)-FMAU Treatment**

Figures 14-20 provide the clinical chemistry of mouse plasma after administration of L-(-)-FMAU at 10 mg/kg (three mice) or 50 mg/kg (three mice) bid for thirty days.

Figure 14 is a bar chart graph of the concentration of total bilirubin in the mouse plasma in mg/dL. Figure 15 is a bar chart graph of the concentration of alkaline phosphatase in the mouse plasma in U/L. Total bilirubin and alkaline phosphatase are indicators of liver function. The mouse values for the bilirubin fall within the normal human range (less than 1.2 mg/dL), but those for alkaline phosphatase are somewhat higher than the normal human level (30-114 U/L).

Figure 16 is a bar chart graph of the concentration of creatinine in the mouse plasma in mg/dL. Creatinine is an index of kidney function. With the exception of mouse 50-2, the creatinine levels of the treated mice are not different from those of the control mice.

Figure 17 is a bar chart graph of the concentration of AST (SGOT, serum glutamic oxalic transaminase) in the mouse plasma in U/L. Figure 18 is a bar chart graph of the concentration of ALT (SGPT, serum glutamic pyruvic transaminase) in the

mouse plasma in U/L. SGOT and SGPT are indicators of liver function. With the exception of mouse 50-2 (for both SGOT and SGPT) and mouse 10-2 (for SGOT only), the enzyme levels of the treated mice are not different from those of the control mice.

Figure 19 is a bar chart graph of the concentration of lactic acid in the mouse plasma in mmol/L. Figure 20 is a bar chart graph of the concentration of lactic dehydrogenase in the mouse plasma in U/L. Lactic acid is formed in muscles during glycolysis. Lactic dehydrogenase (LDH) is present as different isoenzymes in different tissues. Release of LDH into plasma may be an indication of tissue damage. The lactic acid and lactic dehydrogenase levels of the treated mice are not significantly different from those of the control mice.

### III. Oligonucleotides

Oligonucleotides of desired sequences can be modified by substitution of one or more of the L-nucleosides disclosed herein for a nucleoside in the oligonucleotide. In a preferred embodiment the L-nucleoside is placed at one of the termini of the oligonucleotide. The modified oligonucleotide can be used, for example, in antisense technology.

Antisense technology refers in general to the modulation of gene expression through a process wherein a synthetic oligonucleotide is hybridized to a complementary nucleic acid sequence to inhibit transcription or replication (if the target sequence is DNA), inhibit translation (if the target sequence is RNA) or to inhibit processing (if the target sequence is pre-RNA). A wide variety of cellular activities can be modulated using this technique. A simple example is the inhibition of protein biosynthesis by an antisense

oligonucleotide bound to mRNA. In another embodiment, a synthetic oligonucleotide is hybridized to a specific gene sequence in double stranded DNA, forming a triple stranded complex (triplex) that inhibits the expression of that gene sequence. Antisense oligonucleotides can be also used to activate gene expression indirectly by suppressing the biosynthesis of a natural repressor. AOT can be used to inhibit the expression of pathogenic genes, for example, those that facilitate the replication of viruses, including human immunodeficiency virus (HIV), hepatitis B virus (HBV), and herpesviruses, and cancers, particularly solid tumor masses such as gliomas, breast cancer, and melanomas.

The stability of a selected oligonucleotide against nucleases is an important factor for in vivo applications. It is known that 3'-exonuclease activity is responsible for most of the unmodified antisense oligonucleotide degradation in serum. Vlassov, V.V., Yakubov, L.A., in Prospects for Antisense Nucleic Acid Therapy of Cancers and AIDS, 1991, 243-266, Wiley-Liss, Inc., New York; Nucleic Acids Res., 1993, 21, 145. In one embodiment, the L-nucleosides disclosed herein can be used to minimize 3'-exonuclease degradation of antisense oligonucleotides.

Oligonucleotides of the present invention which are capable of binding to polyribonucleic acid or polydeoxyribonucleic acid are useful as antisense agents in the same manner as conventional antisense agents. See generally Antisense Molecular Biology and S-oligos, Synthesis 1 (Oct. 1988) (published by Synthecell Corp., Rockville, Md.); 2 Discoveries in Antisense Nucleic Acids (C. Brakel and R. Fraley eds. 1989); Uhlmann, et. al., "Antisense Oligonucleotides: A New Therapeutic Technique,"

Chem. Rev. 90(4), 1990; and Milligan, J.F.,  
Matteucci, M.D., Martin, J.C., J. Med. Chem., 1993,  
36, 1923-1937. Antisense agents of the present  
invention may be used by constructing an antisense  
5 agent which is capable of selectively binding to a  
predetermined polydeoxyribonucleic acid sequence or  
polyribonucleic acid sequence to a cell containing  
such sequence (e.g., by adding the antisense agent  
to a culture medium containing the cell) so that  
10 the antisense agent is taken into the cell, binds  
to the predetermined sequence, and blocks  
transcription, translation, or replication thereof.  
The requirements for selective binding of the  
antisense agent are known (e.g., a length of 17  
15 bases for selective binding within the human  
genome).

#### IV. Preparation of Pharmaceutical Compositions

The compounds disclosed herein and their  
pharmaceutically acceptable salts, prodrugs, and  
20 derivatives, are useful in the prevention and  
treatment of HBV and EBV infections and other  
related conditions such as anti-HBV or anti-EBV  
antibody positive and HBV- or EBV-positive  
conditions, chronic liver inflammation caused by  
25 HBV, cirrhosis, acute hepatitis, fulminant  
hepatitis, chronic persistent hepatitis, and  
fatigue. These compounds or formulations can also  
be used prophylactically to prevent or retard the  
progression of clinical illness in individuals who  
30 are anti-HBV anti-EBV antibody or HBV- or EBV-  
antigen positive or who have been exposed to HBV or  
EBV.

Humans suffering from any of these conditions  
can be treated by administering to the patient an  
35 effective HBV- or EBV- treatment amount of one or a

mixture of the active compounds described herein or a pharmaceutically acceptable derivative or salt thereof, optionally in a pharmaceutically acceptable carrier or diluent. The active

5 materials can be administered by any appropriate route, for example, orally, parenterally, intravenously, intradermally, subcutaneously, or topically, in liquid or solid form.

The active compound is included in the  
10 pharmaceutically acceptable carrier or diluent in an amount sufficient to deliver to a patient a therapeutically effective amount without causing serious toxic effects in the patient treated.

A preferred dose of the active compound for all  
15 of the above-mentioned conditions will be in the range from about 1 to 60 mg/kg, preferably 1 to 20 mg/kg, of body weight per day, more generally 0.1 to about 100 mg per kilogram body weight of the recipient per day. The effective dosage range of  
20 the pharmaceutically acceptable derivatives can be calculated based on the weight of the parent nucleoside to be delivered. If the derivative exhibits activity in itself, the effective dosage can be estimated as above using the weight of the  
25 derivative, or by other means known to those skilled in the art. In one embodiment, the active compound is administered as described in the product insert or Physician's Desk Reference for 3'-azido-3'-deoxythymidine (AZT), 2',3'-  
30 dideoxyinosine (DDI), 2',3'-dideoxycytidine (DDC), or 2',3'-dideoxy-2',3'-didehydrothymidine (D4T) for HIV indication.

The compound is conveniently administered in unit any suitable dosage form, including but not  
35 limited to one containing 7 to 3000 mg, preferably 70 to 1400 mg of active ingredient per unit dosage



form. A oral dosage of 50-1000 mg is usually convenient.

Ideally the active ingredient should be administered to achieve peak plasma concentrations of the active compound of from about 0.2 to 70  $\mu\text{M}$ , preferably about 1.0 to 10  $\mu\text{M}$ . This may be achieved, for example, by the intravenous injection of a 0.1 to 5% solution of the active ingredient, optionally in saline, or administered as a bolus of the active ingredient.

The active compound can be provided in the form of pharmaceutically acceptable salts. As used herein, the term pharmaceutically acceptable salts or complexes refers to salts or complexes of the nucleosides that retain the desired biological activity of the parent compound and exhibit minimal, if any, undesired toxicological effects. Nonlimiting examples of such salts are (a) acid addition salts formed with inorganic acids (for example, hydrochloric acid, hydrobromic acid, sulfuric acid, phosphoric acid, nitric acid, and the like), and salts formed with organic acids such as acetic acid, oxalic acid, tartaric acid, succinic acid, malic acid, ascorbic acid, benzoic acid, tannic acid, pamoic acid, alginic acid, polyglutamic acid, naphthalenesulfonic acids, naphthalenedisulfonic acids, and polygalacturonic acid; (b) base addition salts formed with cations such as sodium, potassium, zinc, calcium, bismuth, barium, magnesium, aluminum, copper, cobalt, nickel, cadmium, sodium, potassium, and the like, or with an organic cation formed from N,N-dibenzylethylene-diamine, ammonium, or ethylenediamine; or (c) combinations of (a) and (b); e.g., a zinc tannate salt or the like.

Modifications of the active compound, specifically at the N<sup>6</sup> or N<sup>4</sup> and 5'-O positions, can

affect the bioavailability and rate of metabolism of the active species, thus providing control over the delivery of the active species.

5       The concentration of active compound in the drug composition will depend on absorption, inactivation, and excretion rates of the drug as well as other factors known to those of skill in the art. It is to be noted that dosage values will also vary with the severity of the condition to be  
10       alleviated. It is to be further understood that for any particular subject, specific dosage regimens should be adjusted over time according to the individual need and the professional judgment of the person administering or supervising the  
15       administration of the compositions, and that the concentration ranges set forth herein are exemplary only and are not intended to limit the scope or practice of the claimed composition. The active ingredient may be administered at once, or may be  
20       divided into a number of smaller doses to be administered at varying intervals of time.

      A preferred mode of administration of the active compound is oral. Oral compositions will generally include an inert diluent or an edible carrier.  
25       They may be enclosed in gelatin capsules or compressed into tablets. For the purpose of oral therapeutic administration, the active compound can be incorporated with excipients and used in the form of tablets, troches, or capsules.  
30       Pharmaceutically compatible binding agents, and/or adjuvant materials can be included as part of the composition.

      The tablets, pills, capsules, troches and the like can contain any of the following ingredients,  
35       or compounds of a similar nature: a binder such as microcrystalline cellulose, gum tragacanth or gelatin; an excipient such as starch or lactose, a

disintegrating agent such as alginic acid, Primogel, or corn starch; a lubricant such as magnesium stearate or Sterotes; a glidant such as colloidal silicon dioxide; a sweetening agent such as sucrose or saccharin; or a flavoring agent such as peppermint, methyl salicylate, or orange flavoring. When the dosage unit form is a capsule, it can contain, in addition to material of the above type, a liquid carrier such as a fatty oil. In addition, dosage unit forms can contain various other materials which modify the physical form of the dosage unit, for example, coatings of sugar, shellac, or other enteric agents.

The active compound or pharmaceutically acceptable salt or derivative thereof can be administered as a component of an elixir, suspension, syrup, wafer, chewing gum or the like. A syrup may contain, in addition to the active compounds, sucrose as a sweetening agent and certain preservatives, dyes and colorings and flavors.

The active compound, or pharmaceutically acceptable derivative or salt thereof can also be mixed with other active materials that do not impair the desired action, or with materials that supplement the desired action, such as antibiotics, antifungals, antiinflammatories, or other antivirals, including anti-HBV, anti-EBV, anti-cytomegalovirus, or anti-HIV or anti-EBV agents.

Solutions or suspensions used for parenteral, intradermal, subcutaneous, or topical application can include the following components: a sterile diluent such as water for injection, saline solution, fixed oils, polyethylene glycols, glycerine, propylene glycol or other synthetic solvents; antibacterial agents such as benzyl alcohol or methyl parabens; antioxidants such as

ascorbic acid or sodium bisulfite; chelating agents such as ethylenediaminetetraacetic acid; buffers such as acetates, citrates or phosphates and agents for the adjustment of tonicity such as sodium chloride or dextrose. The parental preparation can be enclosed in ampoules, disposable syringes or multiple dose vials made of glass or plastic.

If administered intravenously, preferred carriers are physiological saline or phosphate buffered saline (PBS). In a preferred embodiment, the active compounds are prepared with carriers that will protect the compound against rapid elimination from the body, such as a controlled release formulation, including implants and microencapsulated delivery systems. Biodegradable, biocompatible polymers can be used, such as ethylene vinyl acetate, polyanhydrides, polyglycolic acid, collagen, polyorthoesters, and polylactic acid. Methods for preparation of such formulations will be apparent to those skilled in the art. The materials can also be obtained commercially from Alza Corporation and Nova Pharmaceuticals, Inc.

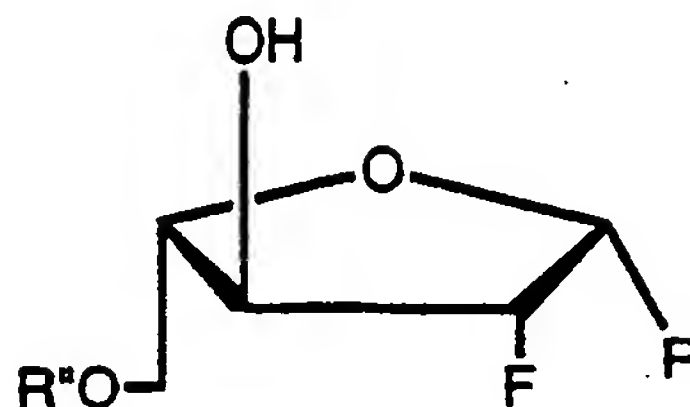
Liposomal suspensions (including liposomes targeted to infected cells with monoclonal antibodies to viral antigens) are also preferred as pharmaceutically acceptable carriers. These may be prepared according to methods known to those skilled in the art, for example, as described in U.S. Patent No. 4,522,811 (which is incorporated herein by reference in its entirety). For example, liposome formulations may be prepared by dissolving appropriate lipid(s) (such as stearyl phosphatidyl ethanolamine, stearyl phosphatidyl choline, arachadoyl phosphatidyl choline, and cholesterol) in an inorganic solvent that is then evaporated, leaving behind a thin film of dried lipid on the

surface of the container. An aqueous solution of the active compound or its monophosphate, diphosphate, and/or triphosphate derivatives are then introduced into the container. The container  
5 is then swirled by hand to free lipid material from the sides of the container and to disperse lipid aggregates, thereby forming the liposomal suspension.

This invention has been described with reference  
10 to its preferred embodiments. Variations and modifications of the invention, will be obvious to those skilled in the art from the foregoing detailed description of the invention. It is  
intended that all of these variations and  
15 modifications be included within the scope of the appended claims.

We claim.

1. An L-nucleoside compound of the formula:

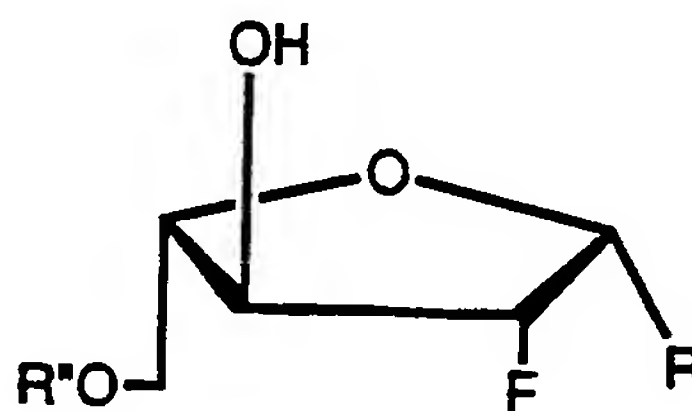


wherein R is a purine or pyrimidine base and R'' is hydrogen, acyl, alkyl, monophosphate, diphosphate, or triphosphate.

2. Use of a compound of claim 1 and pharmaceutically acceptable salts thereof in the manufacture of a medicament for treatment of an EBV or HBV infection.

3. An L-nucleoside of claim 1 and pharmaceutically acceptable salts thereof in the manufacture of a medicament for the treatment of an EBV or HBV infection.

4. A method for the treatment of a human infected with HBV or EBV is provided that includes administering an HBV- or EBV-treatment amount of an L-nucleoside of the formula:



wherein R is a purine or pyrimidine base and R'' is hydrogen, acyl, alkyl, monophosphate, diphosphate, or triphosphate.

5. The method of claim 4, wherein the L-nucleoside is 2'-fluoro-5-methyl- $\beta$ -L-arabinofuranosyluridine.

6. The L-nucleoside of claim 1 that is 2'-fluoro-5-methyl- $\beta$ -L-arabinofuranosyluridine.

7. The L-nucleoside of claim 1 or 3 selected from the group consisting of N<sub>1</sub>-(2'-deoxy-2'-fluoro- $\beta$ -L-arabinofuranosyl)-5-ethyluracil, N<sub>1</sub>-(2'-deoxy-2'-fluoro- $\beta$ -L-arabinofuranosyl)-5-iodocytosine), and N<sub>1</sub>-(2'-deoxy-2'-fluoro- $\beta$ -L-arabinofuranosyl)-5-iodouracil.

8. The L-nucleoside of claim 1 or 3, wherein the base is selected from the group consisting of 5-methyl uracil (thymine), 5-iodouracil, cytosine, and 5-ethyluracil.

9. The use of claim 2, wherein the L-nucleoside is 2'-fluoro-5-methyl- $\beta$ -L-arabinofuranosyluridine.

10. The use of claim 2, wherein the L-nucleoside is selected from the group consisting of N<sub>1</sub>-(2'-deoxy-2'-fluoro- $\beta$ -L-arabinofuranosyl)-5-ethyluracil, N<sub>1</sub>-(2'-deoxy-2'-fluoro- $\beta$ -L-arabinofuranosyl)-5-iodocytosine), and N<sub>1</sub>-(2'-deoxy-2'-fluoro- $\beta$ -L-arabinofuranosyl)-5-iodouracil.

11. The use of claim 2, wherein the base is selected from the group consisting of 5-methyl uracil (thymine), 5-iodouracil, cytosine, and 5-ethyluracil.

12. The method of claim 4, wherein the L-nucleoside is selected from the group consisting of N<sub>1</sub>-(2'-deoxy-2'-fluoro- $\beta$ -L-arabinofuranosyl)-5-ethyluracil, N<sub>1</sub>-(2'-deoxy-2'-fluoro- $\beta$ -L-arabinofuranosyl)-5-iodocytosine), and N<sub>1</sub>-(2'-deoxy-2'-fluoro- $\beta$ -L-arabinofuranosyl)-5-iodouracil.

13. The method of claim 4, wherein the base is selected from the group consisting of 5-methyl uracil (thymine), 5-iodouracil, cytosine, and 5-ethyluracil.



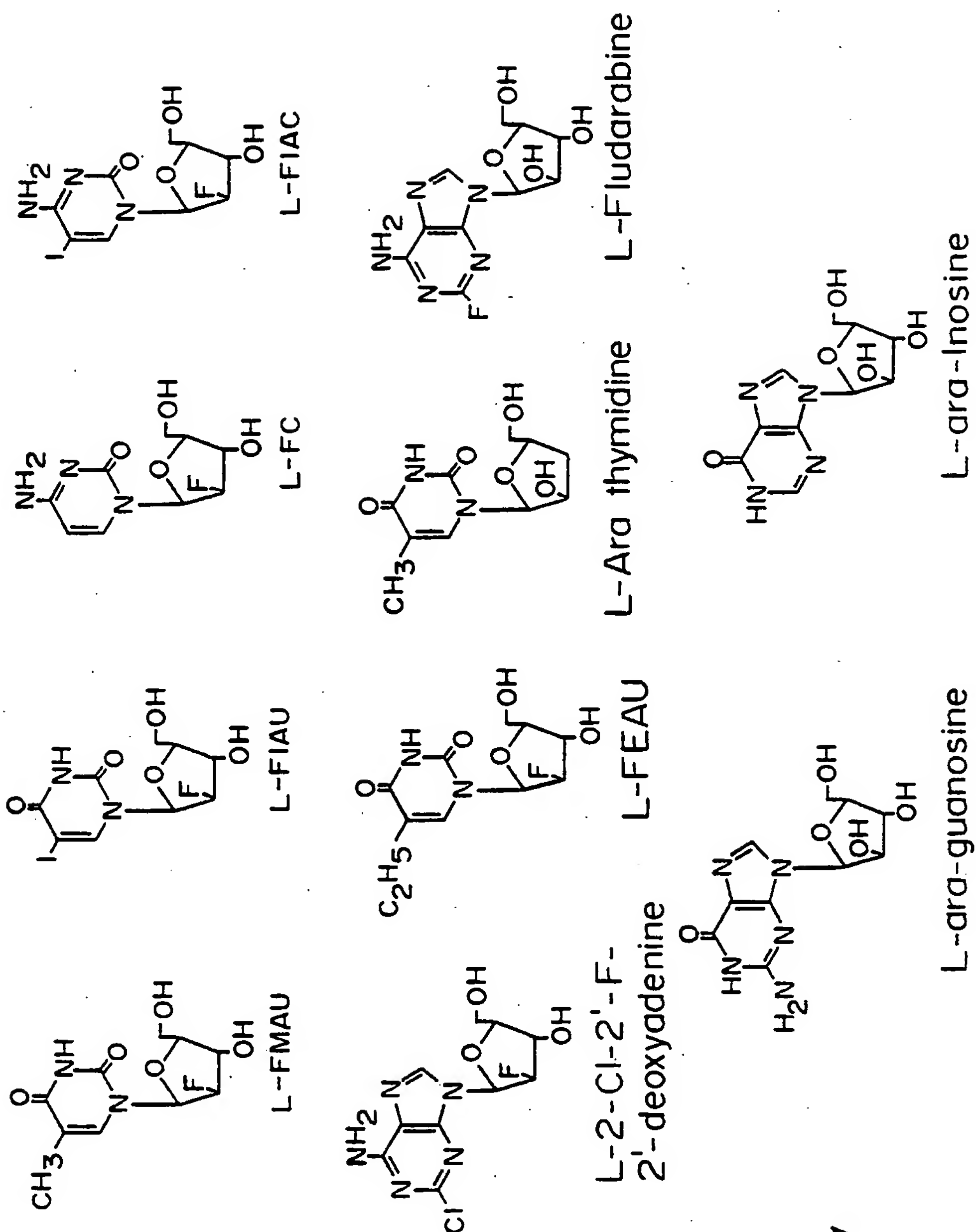


FIG. 1

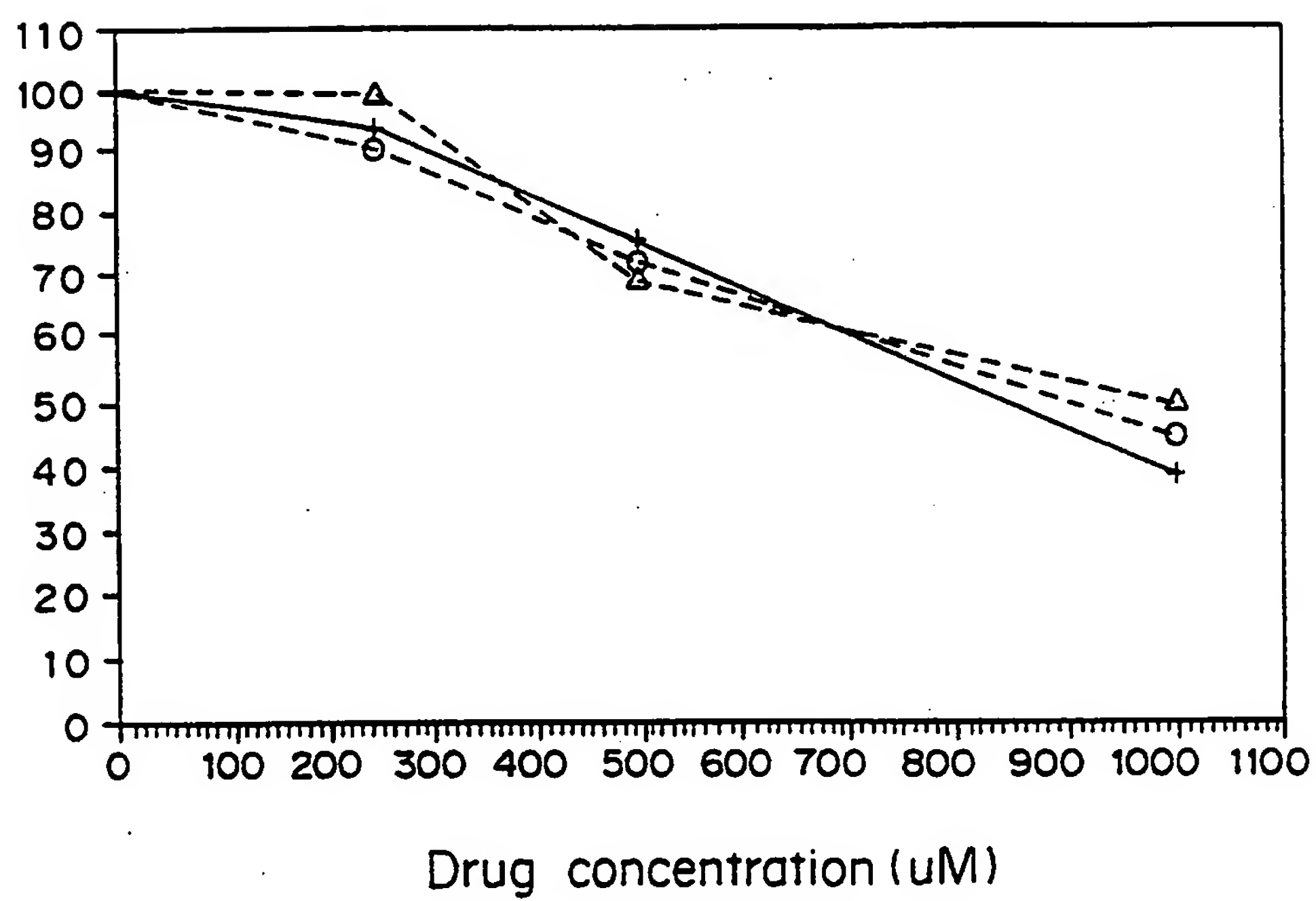
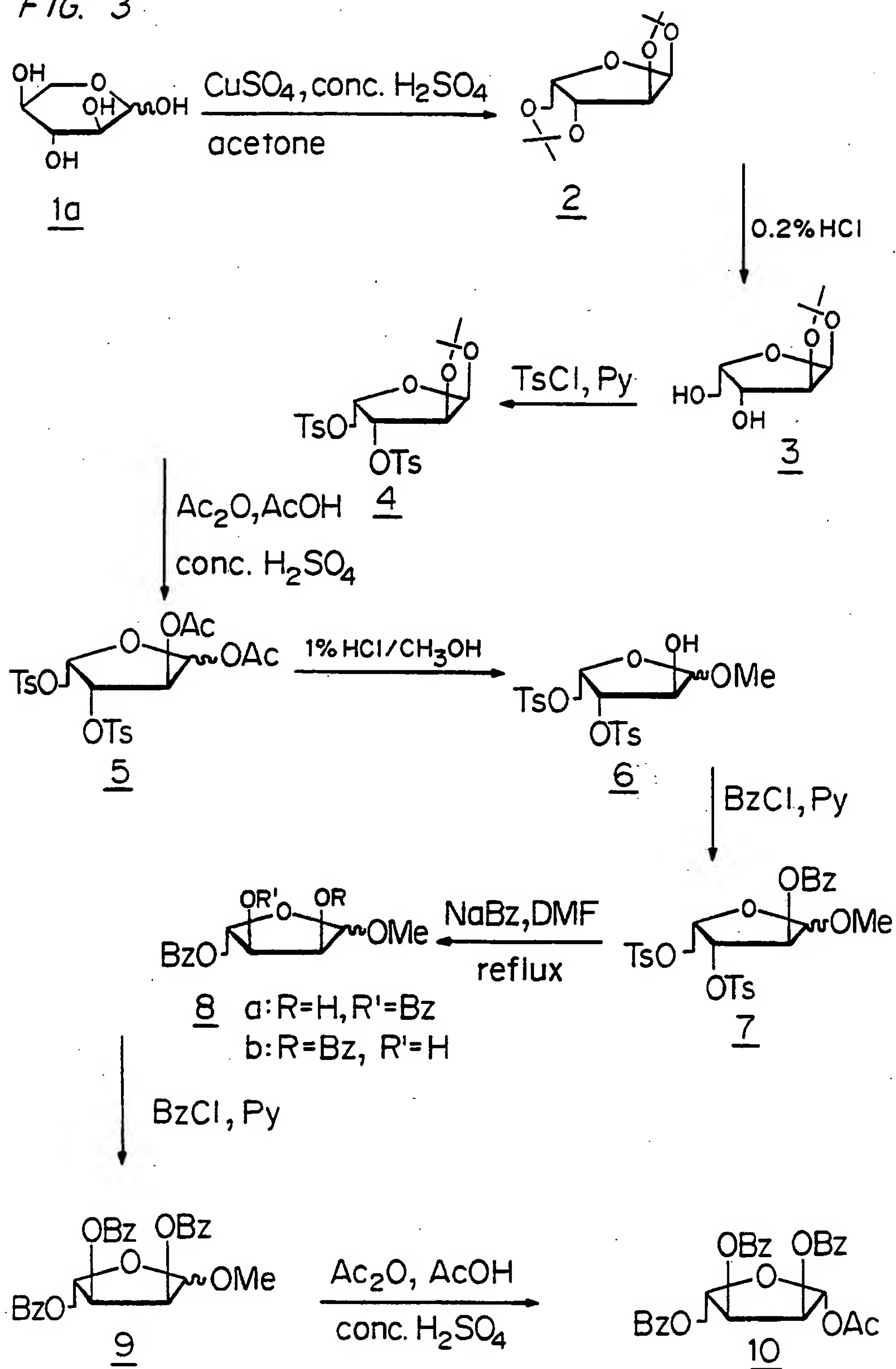
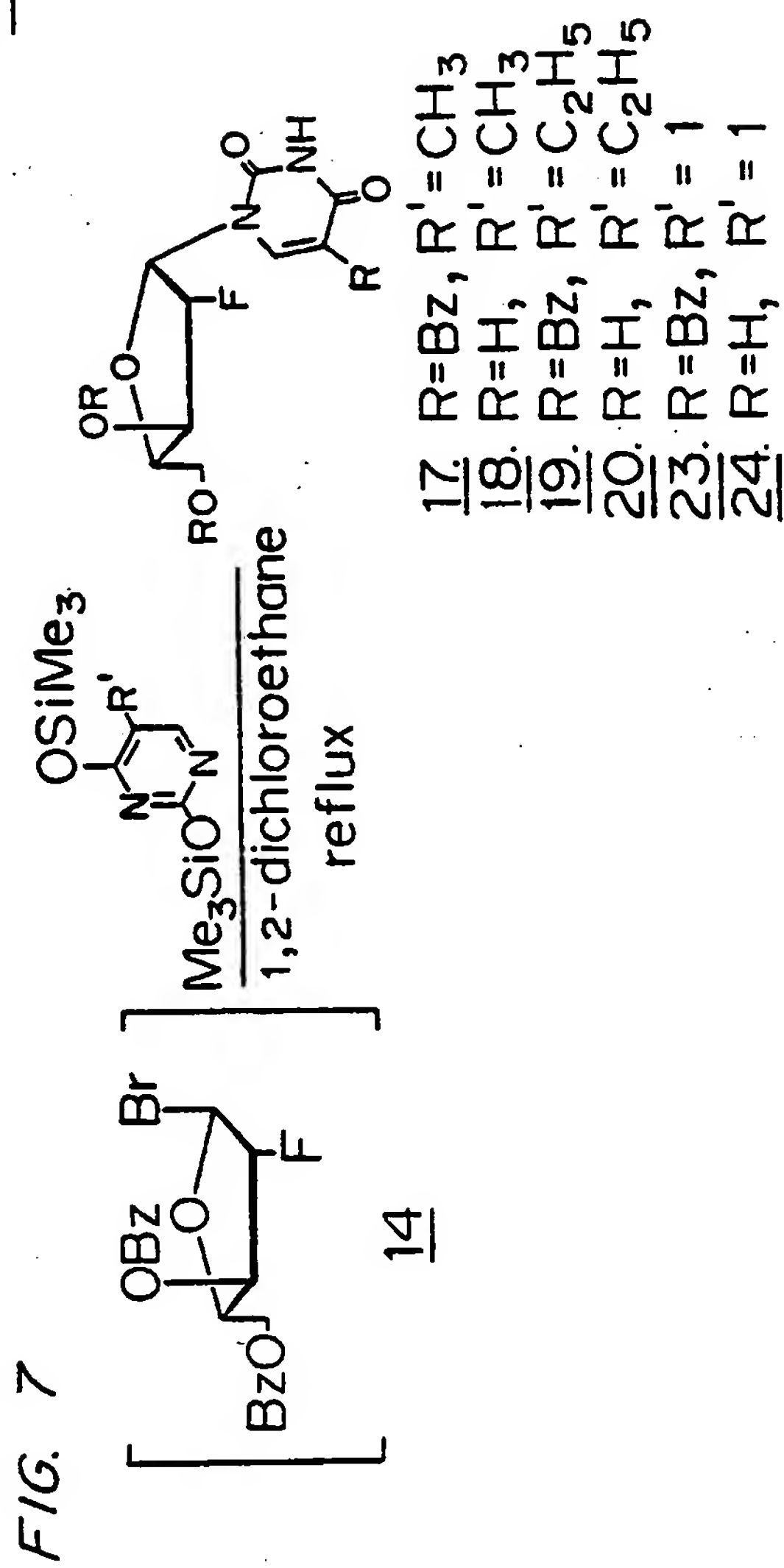
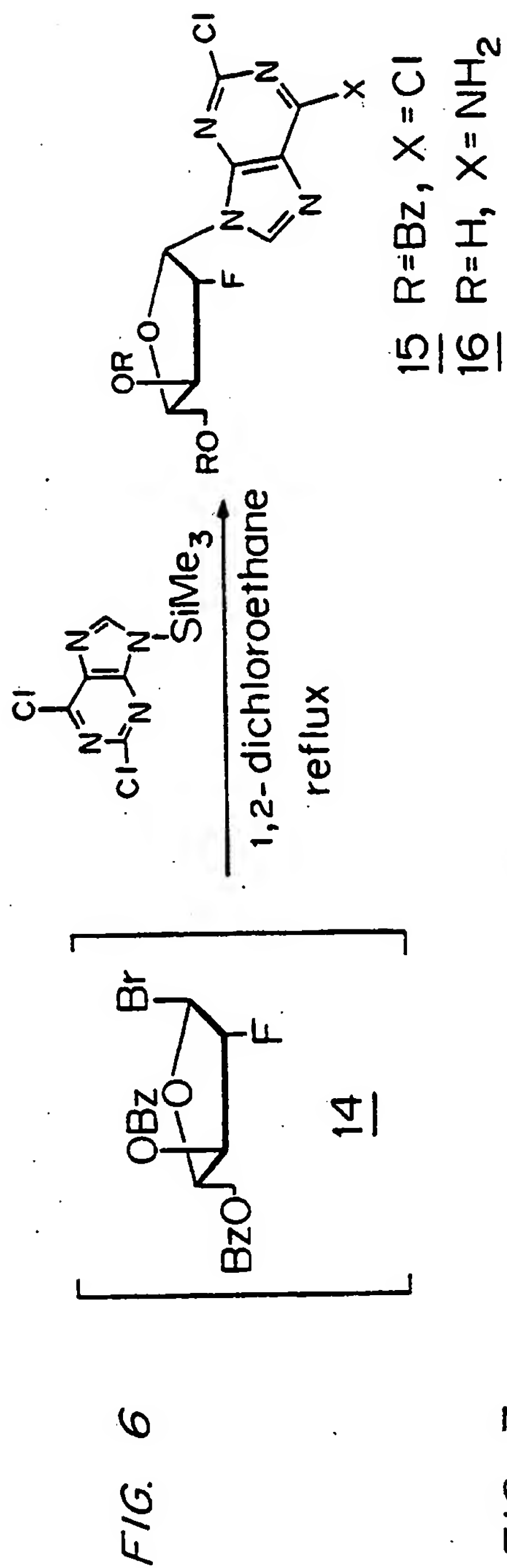


FIG. 2

FIG. 3







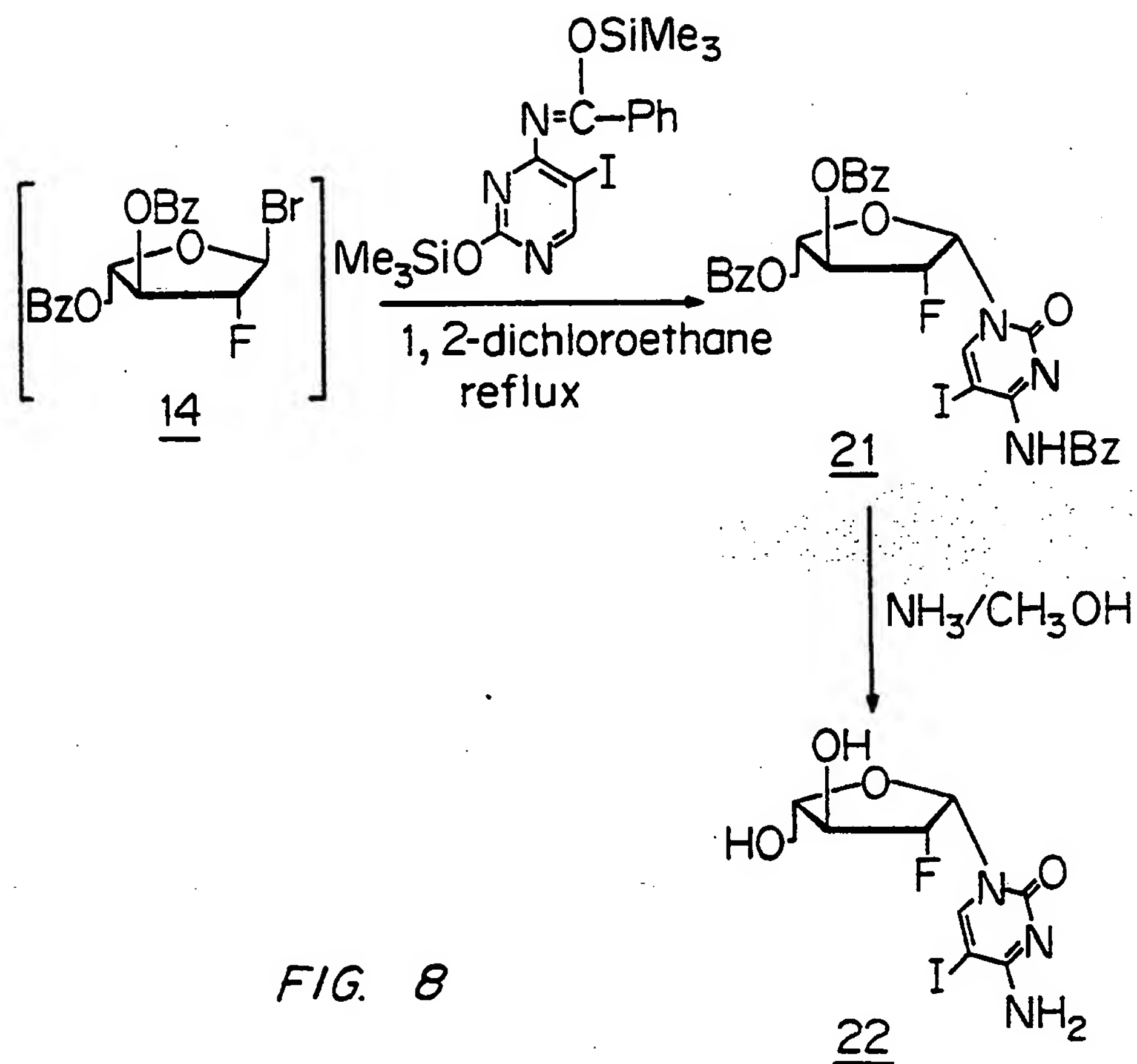


FIG. 8

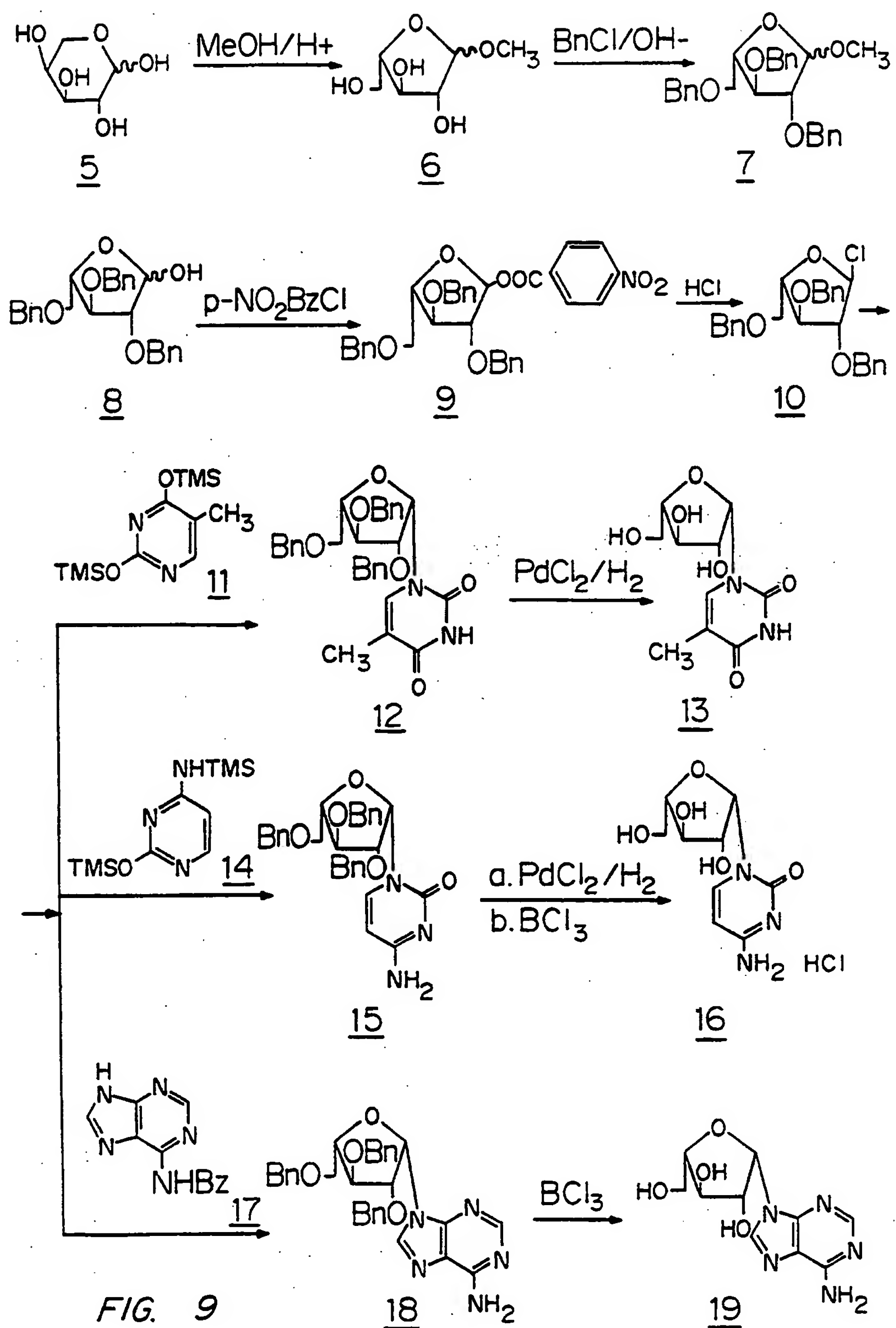


FIG. 9



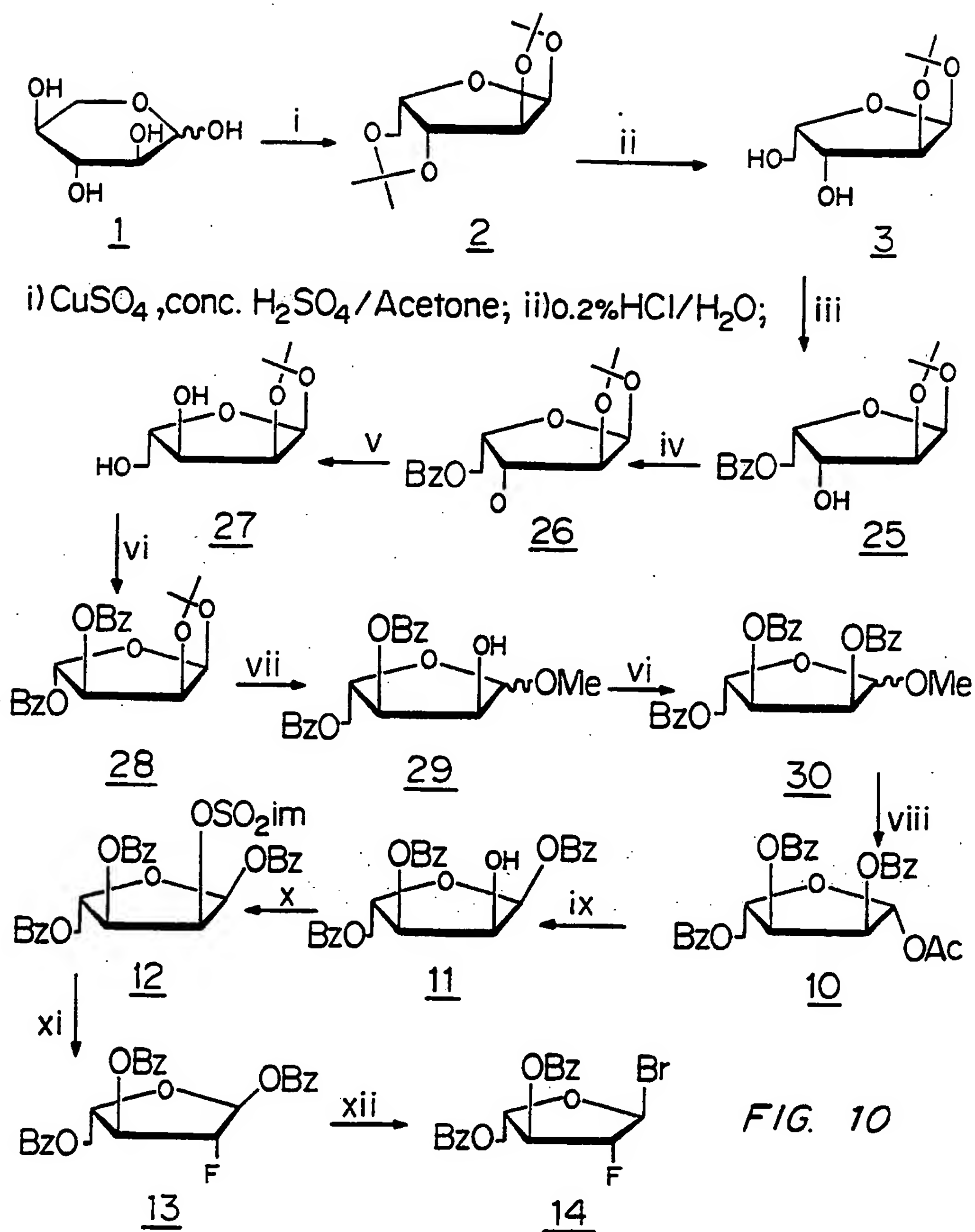


FIG. 10

- iii) BzCl/Py/ $\text{CH}_2\text{Cl}_2$ ,  $0^\circ\text{C}$ , 0.5 hr. ; iv) PDC/ $\text{Ac}_2\text{O}$ / $\text{CH}_2\text{Cl}_2$ , reflux;  
 v)  $\text{NaBH}_4$  / 95% EtOH; vi) BzCl/Py; vii) 1% HCl/ $\text{CH}_3\text{OH}$   
 viii)  $\text{Ac}_2\text{O}$ / $\text{AcOH}$ / $\text{H}_2\text{SO}_4$ ; ix) HCl(g)/ $\text{AcCl}$ / $\text{CH}_2\text{Cl}_2$ ,  $0^\circ\text{C}$ ,  $\text{H}_2\text{O}$ ;  
 x)  $\text{SO}_2\text{Cl}_2$ , imidazole/DMF/ $\text{CH}_2\text{Cl}_2$ ,  $-15^\circ\text{C}$  to r.t.;  
 xi)  $\text{KHF}_2$ , 48% HF/ $\text{H}_2\text{O}$ /2, 3-butanediol,  $\text{N}_2$ , reflux;  
 xii) HBr/ $\text{AcOH}$ / $\text{CH}_2\text{Cl}_2$ , r.t.

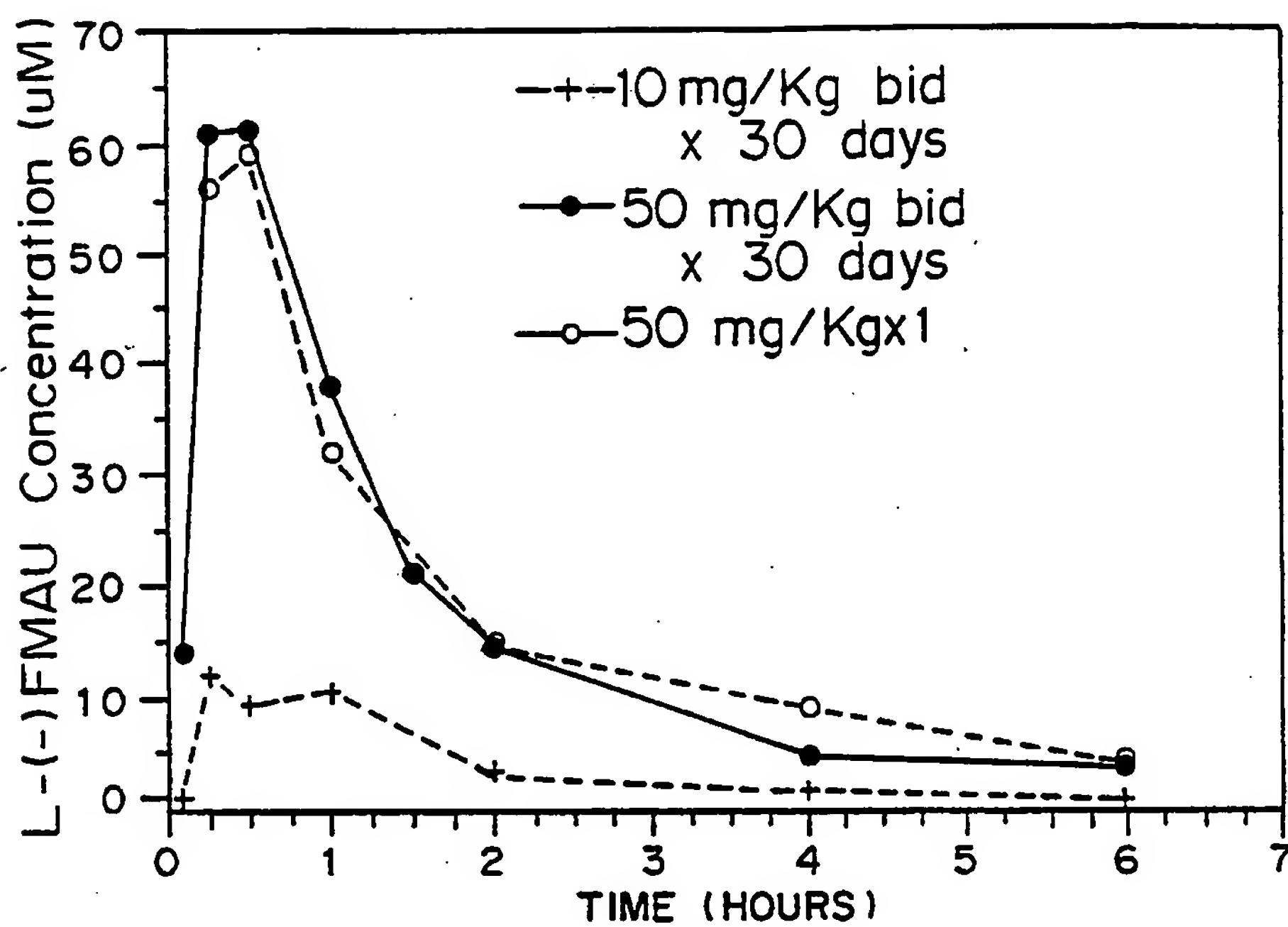


FIG. 11

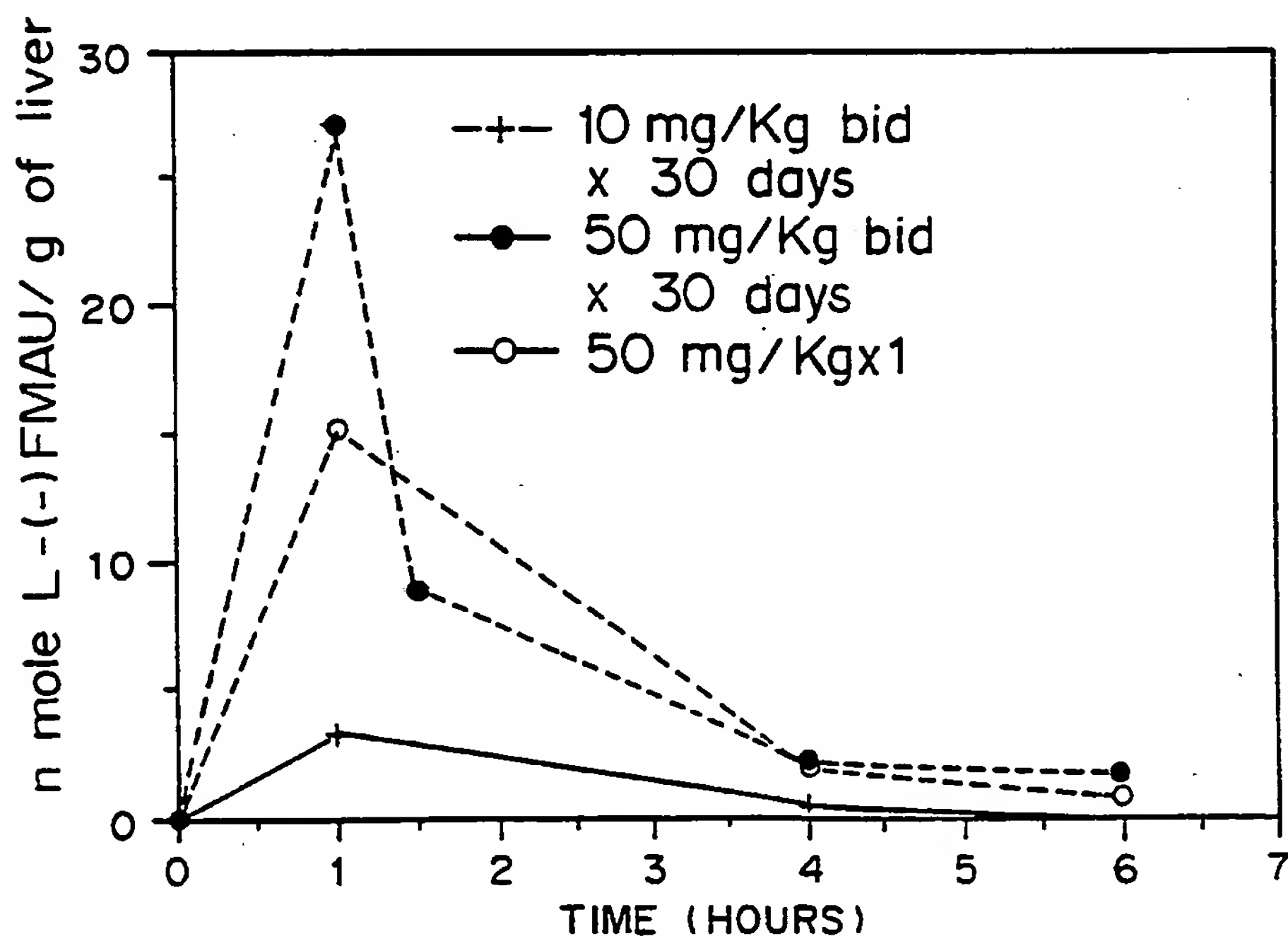
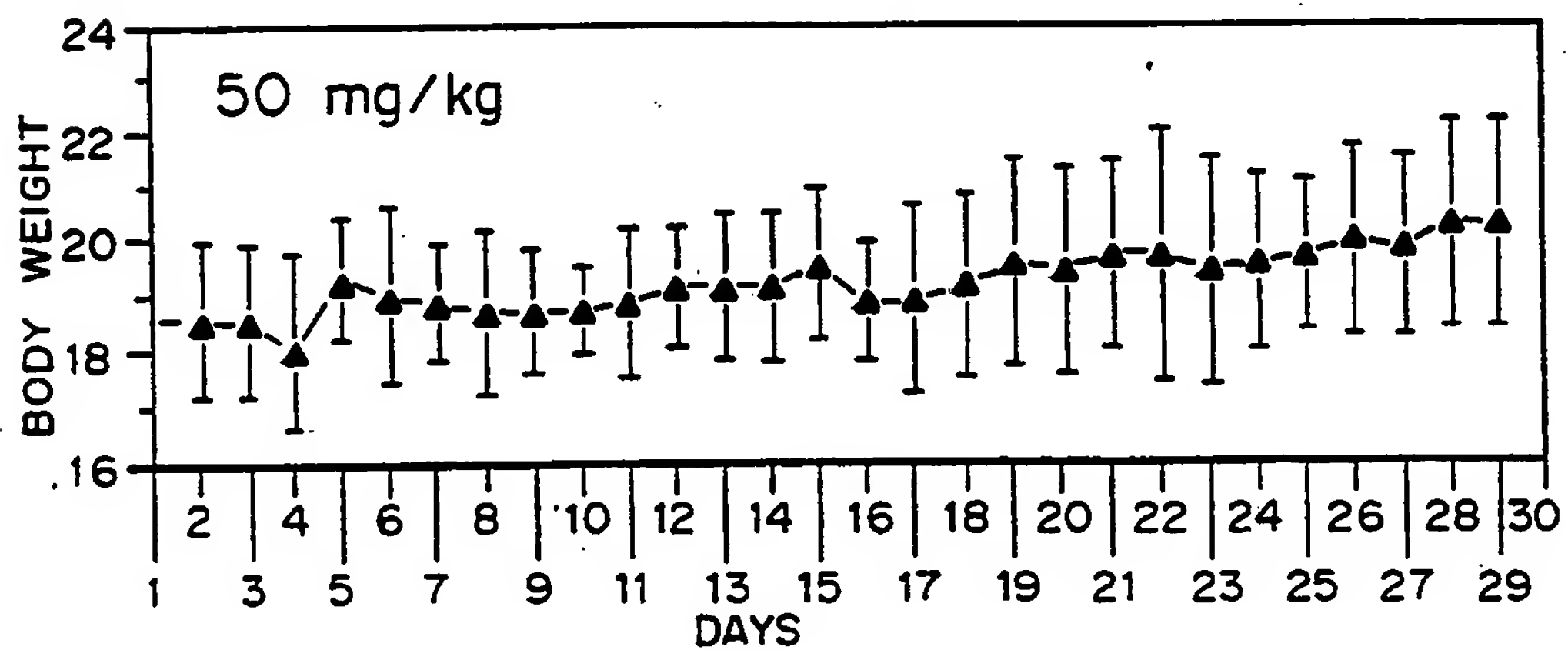
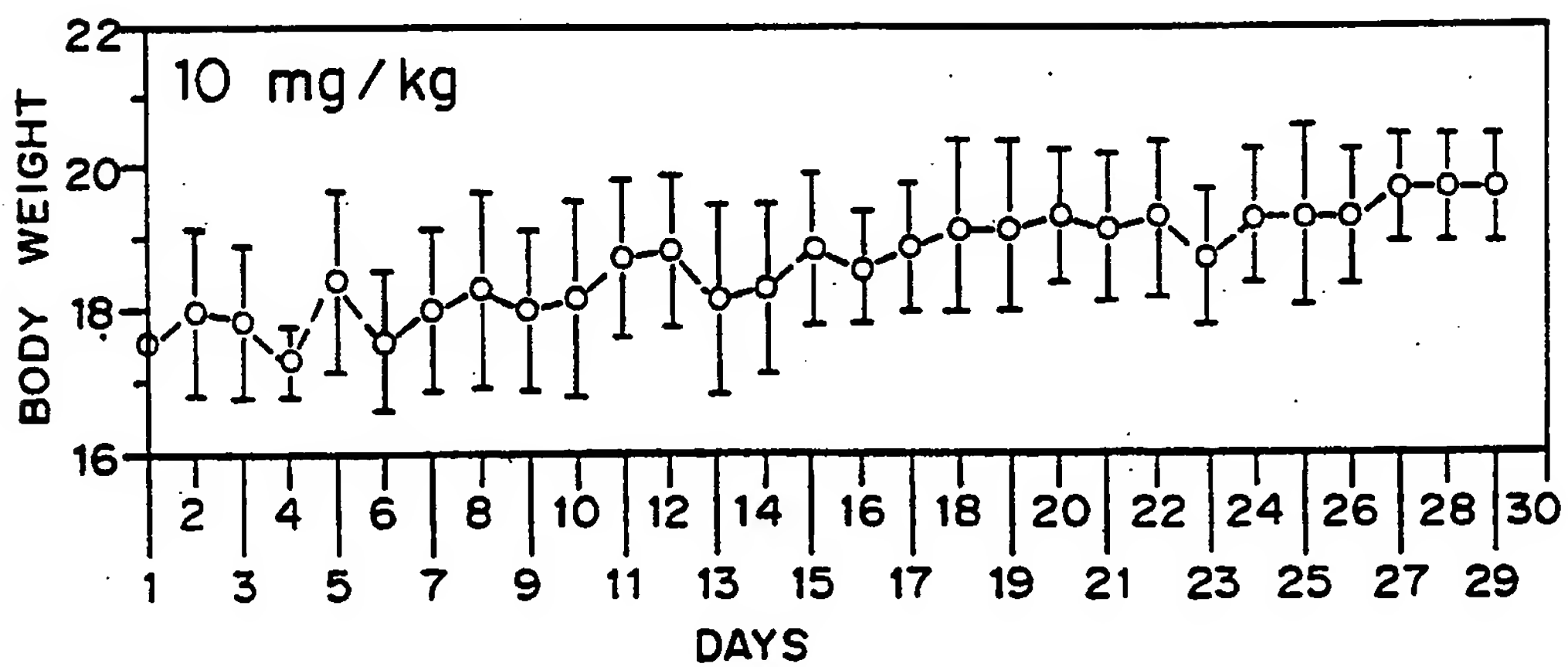
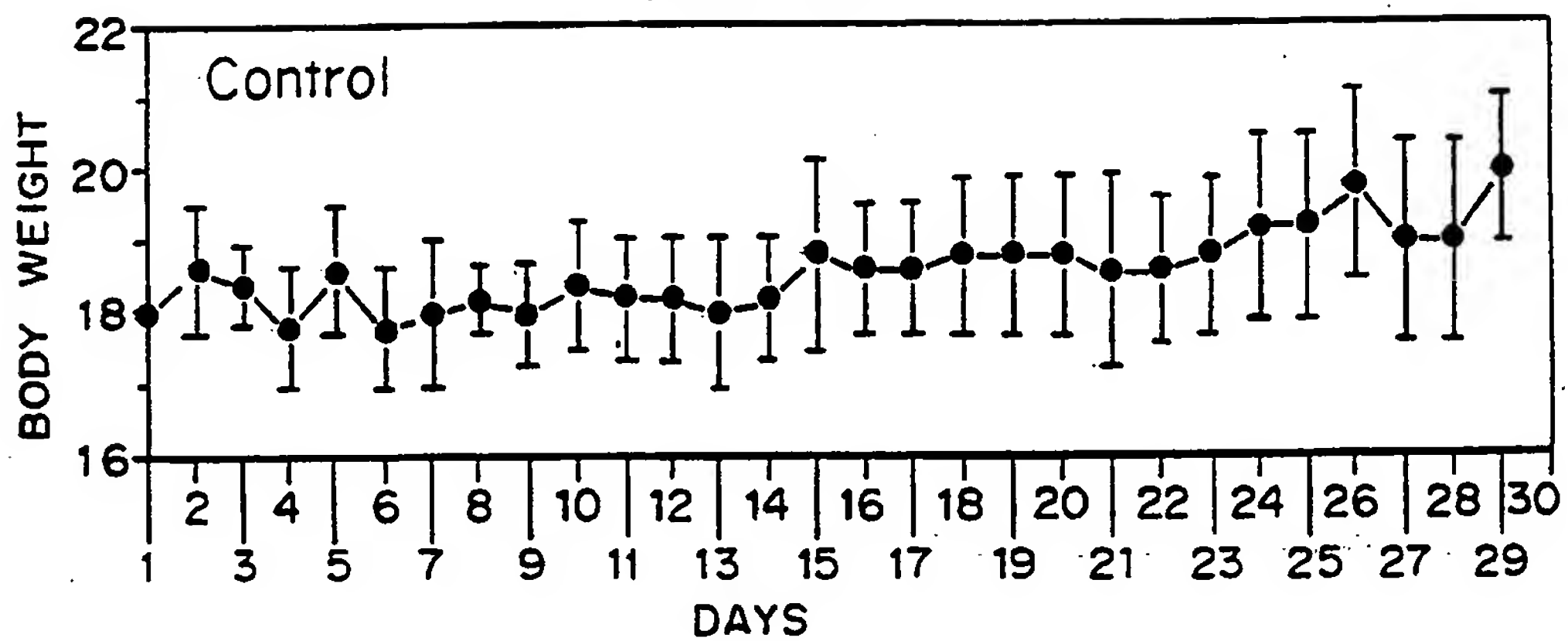


FIG. 12

FIG. 13



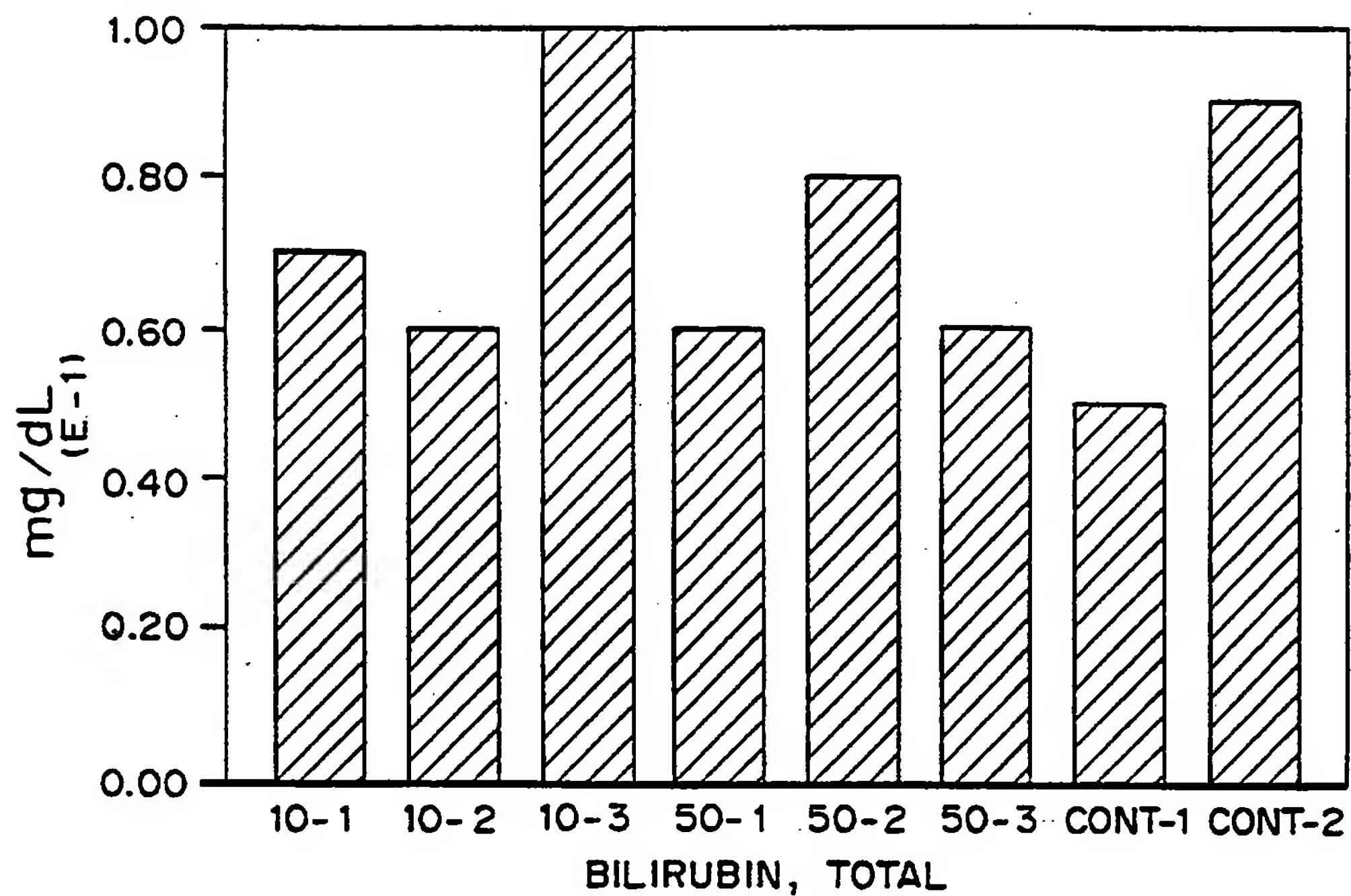


FIG. 14

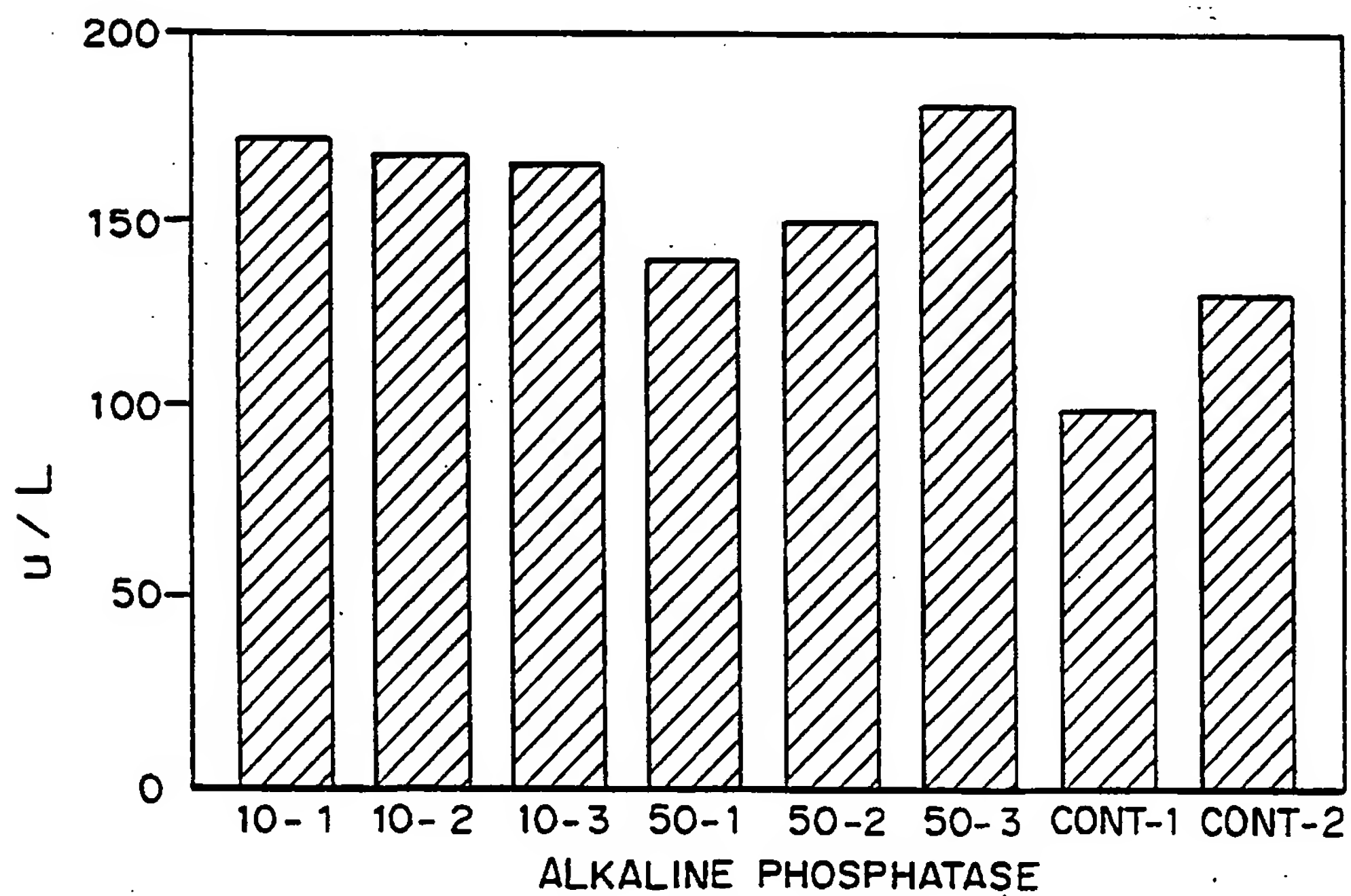


FIG. 15

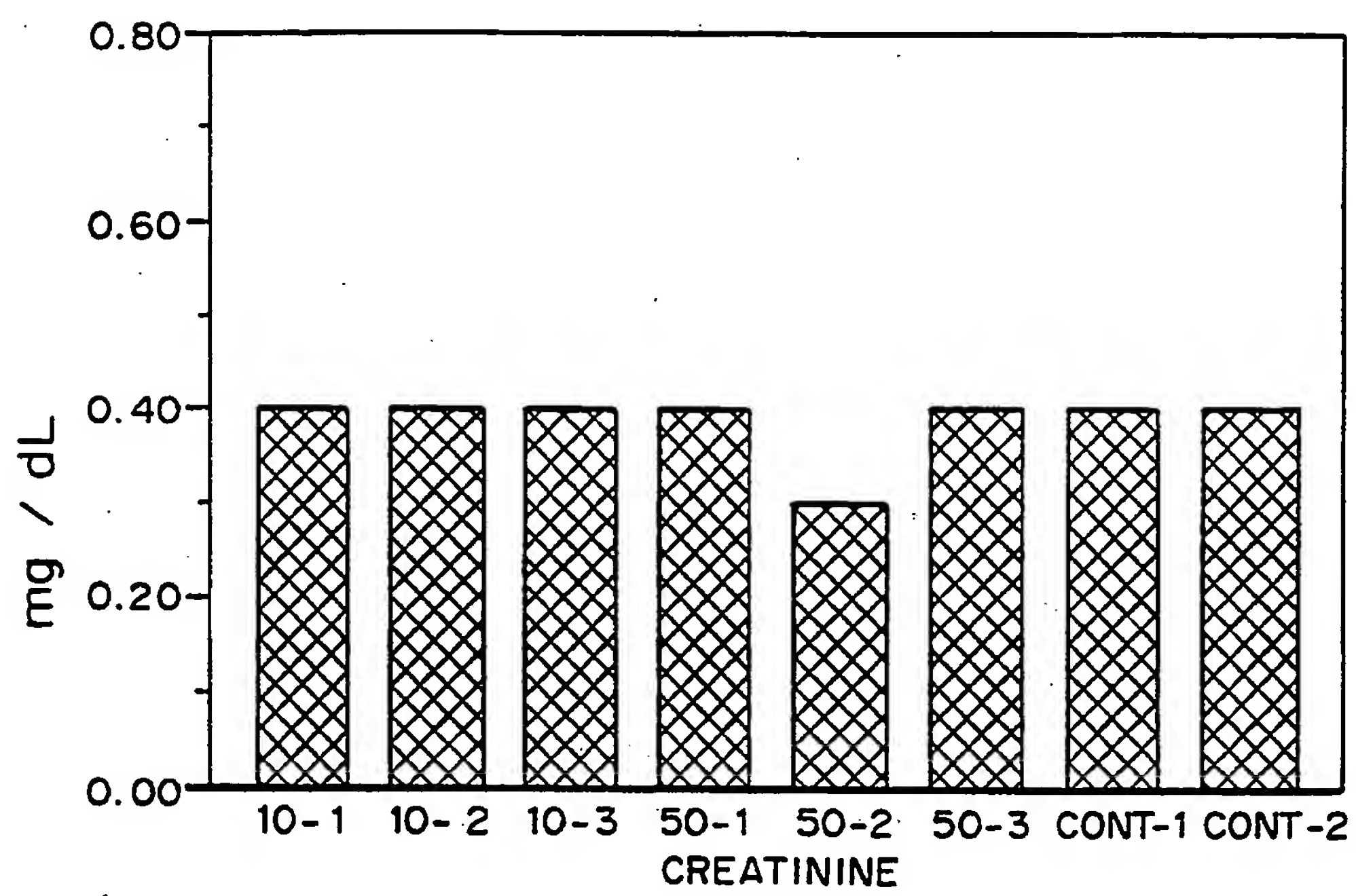


FIG. 16

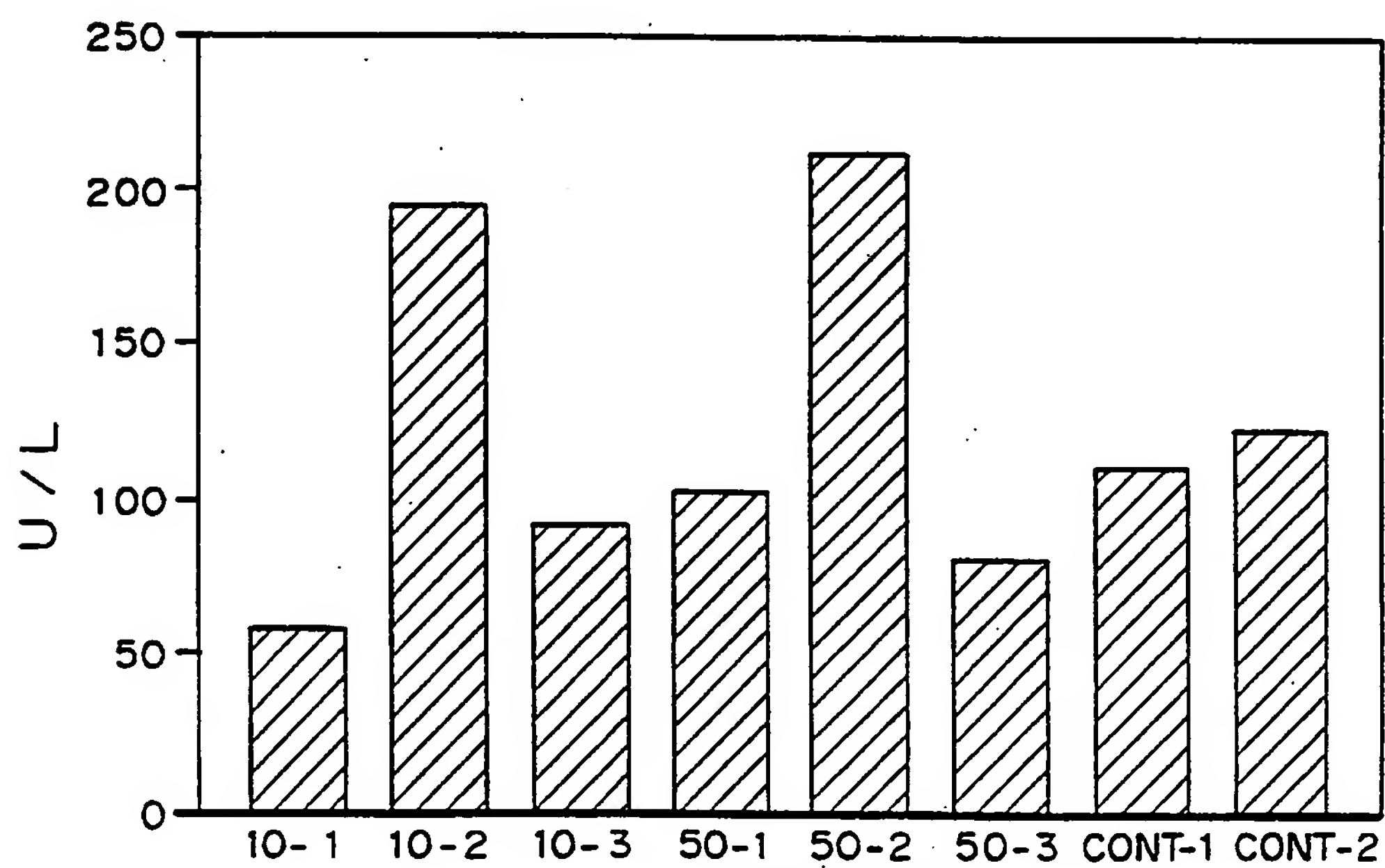


FIG. 17

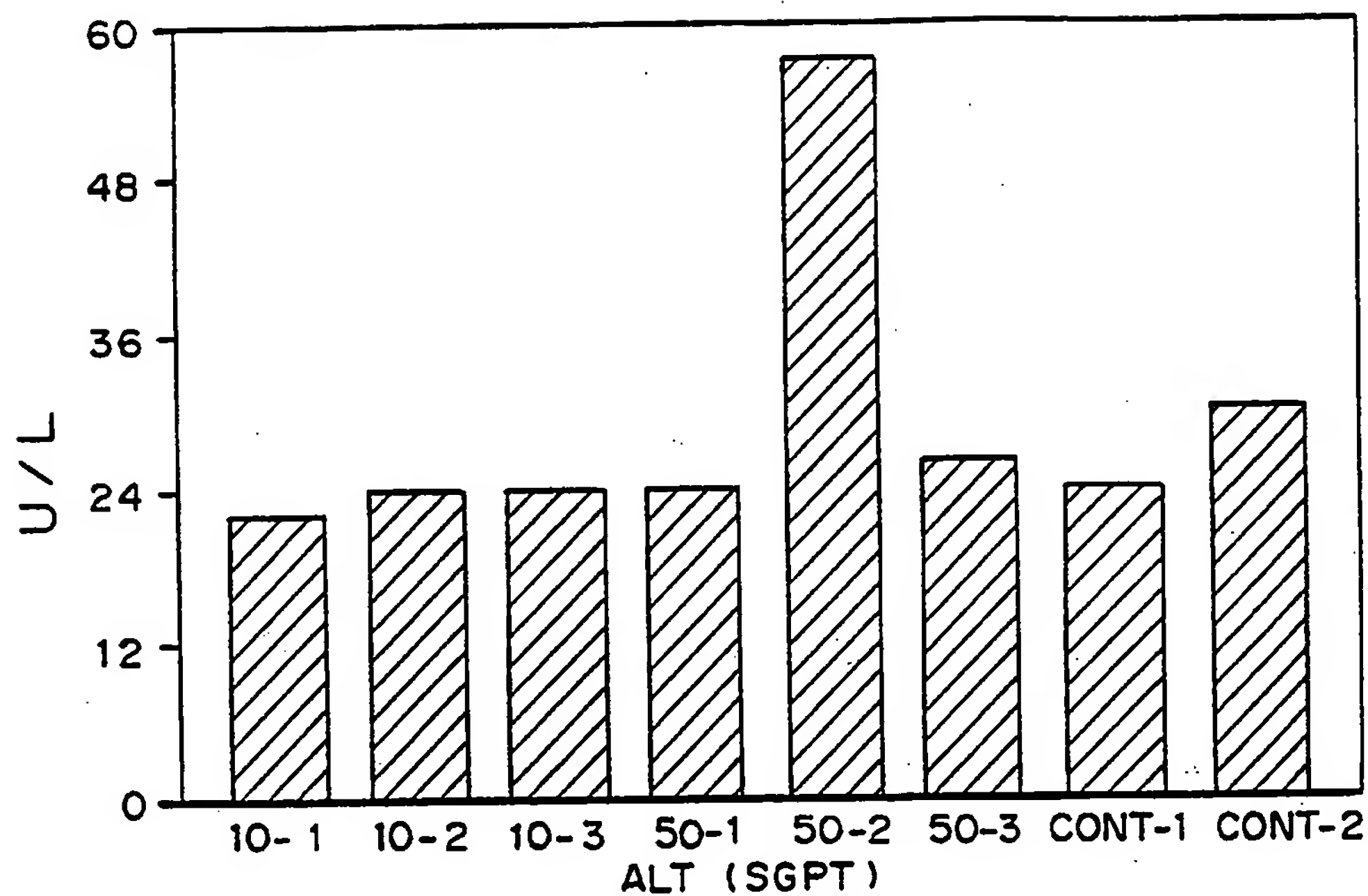


FIG. 18

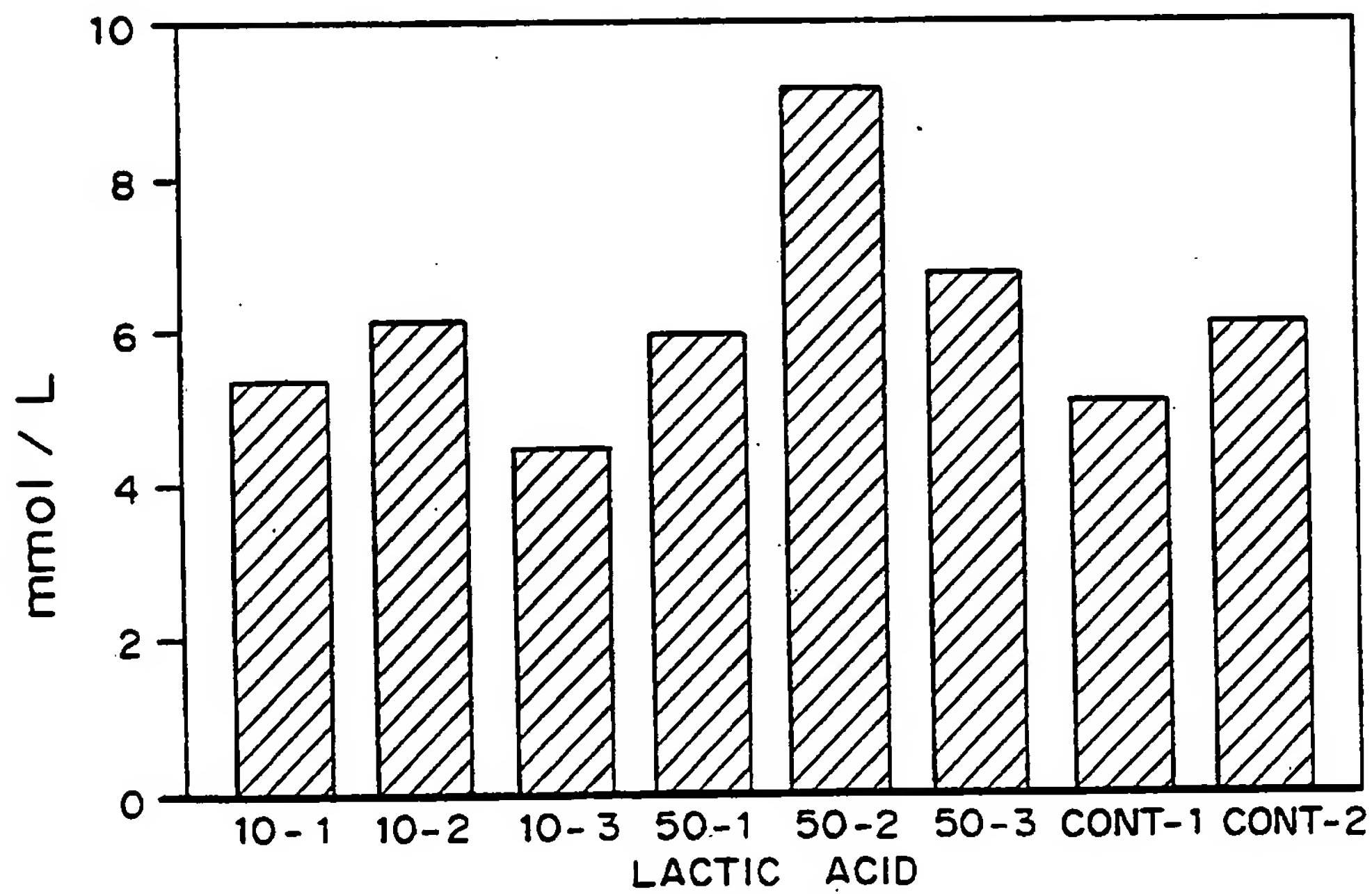
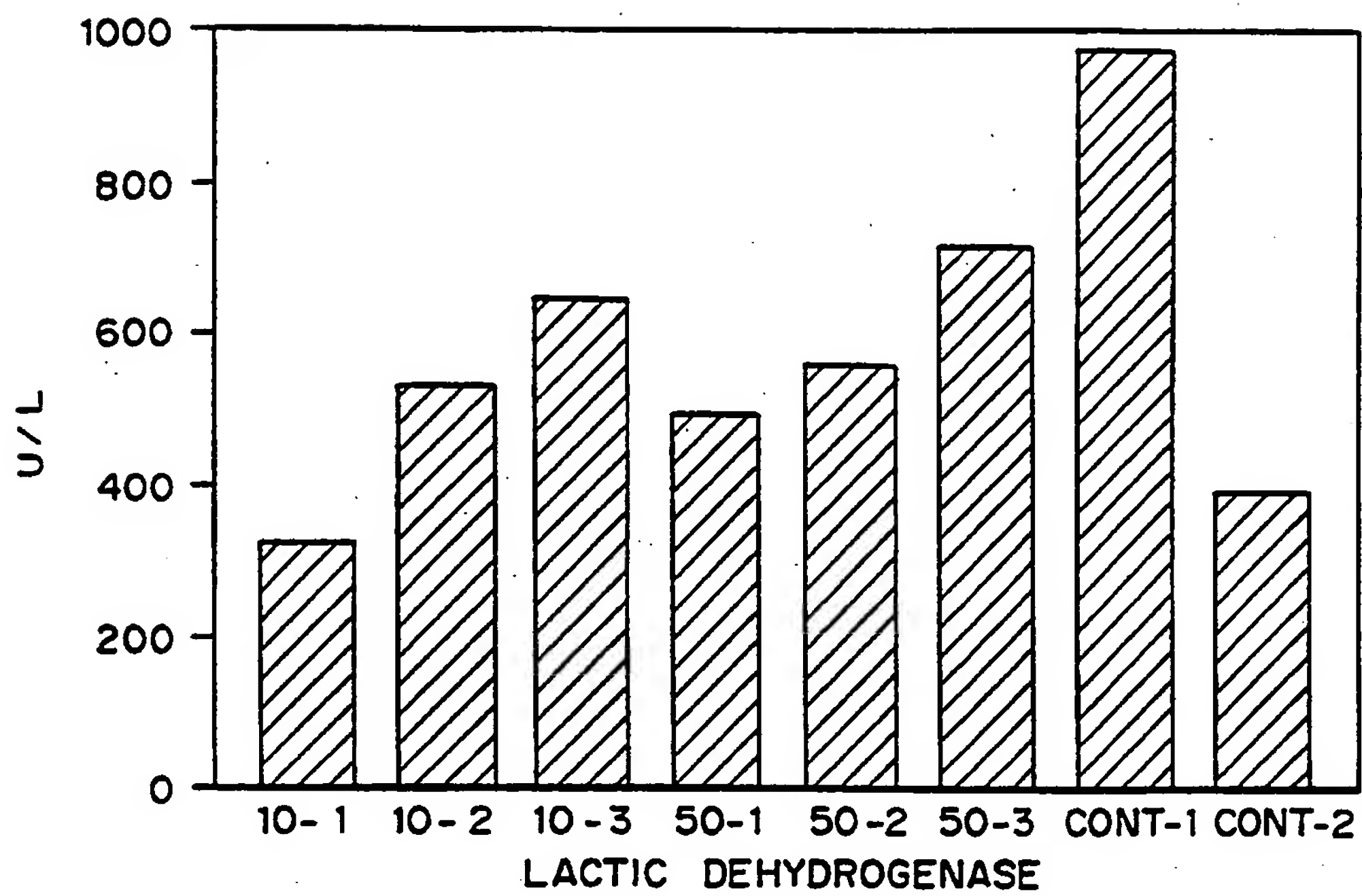


FIG. 19

*FIG. 20*